St. Petersburg University

Graduate School of Management

Master in Management Program

The "Belt and Road Initiative" container terminals' throughput handling capacity: measurement of current performance in search for improvement

Master's thesis by the 2nd year student

Master in Management program

Chen Shenglong

Academic advisor: Associate Professor

Y.V. Fedotov

St. Petersburg

2020

ЗАЯВЛЕНИЕ О САМОСТОЯТЕЛЬНОМ ХАРАКТЕРЕ ВЫПОЛНЕНИЯ ВЫПУСКНОЙ КВАЛИФИКАЦИОННОЙ РАБОТЫ

Я, ___Чэнь Шэнлун___________, студент второго курса магистратурынаправления «Менеджмент», заявляю, что в моей магистерской диссертации на тему « Пропускеая способность контейнерных терминалов, задействованных в ‘Инициатива Пояса и пути’: измерение текущей эффективности в целях её повышения », представленной в службу обеспечения программ магистратуры для последующей передачи в государственную аттестационную комиссию для публичной защиты, не содержится элементов плагиата.

Все прямые заимствования из печатных и электронных источников, а также из защищенных ранее выпускных квалификационных работ, кандидатских и докторских диссертаций имеют соответствующие ссылки.

Мне известно содержание п. 9.7.1 Правил обучения по основным образовательным программам высшего и среднего профессионального образования в СПбГУ о том, что «ВКР выполняется индивидуально каждым студентом под руководством назначенного ему научного руководителя», и п. 51 Устава федерального государственного бюджетного образовательного учреждения высшего образования «Санкт-Петербургский государственный университет» о том, что «студент подлежит отчислению из Санкт-Петербургского университета за представление курсовой или выпускной квалификационной работы, выполненной другим лицом (лицами)».

Чэнь Шэнлун (Подпись студента)

_____04.06.202_____ (Дата)

STATEMENT ABOUT THE INDEPENDENT CHARACTER OF THE MASTER THESIS

I, _____Chen Shenglong_____________, (second) year master student, program «Management», state that my master thesis on the topic « The ‘Belt and Road Initiative’ container terminals’ throughput handling capacity: measurement of current performance in search for improvement », which is presented to the Master Office to be submitted to the Official Defense Committee for the public defense, does not contain any elements of plagiarism.

All direct borrowings from printed and electronic sources, as well as from master theses, PhD and doctorate theses which were defended earlier, have appropriate references.

I am aware that according to paragraph 9.7.1. of Guidelines for instruction in major curriculum programs of higher and secondary professional education at St. Petersburg University «A master thesis must be completed by each of the degree candidates individually under the supervision of his or her advisor», and according to paragraph 51 of Charter of the Federal State Institution of Higher Education Saint-Petersburg State University «a student can be expelled from St. Petersburg University for submitting of the course or graduation qualification work developed by other person (persons)».

Chen Shenglong (Student’s signature)

_______04.06.2020_____ (Date)

АННОТАЦИЯ

Автор	Чэнь Шэнлун
Название ВКР	Пропуская способность контейнерных терминалов, задействованных в "Инициативе Пояса и Пути": измерение текущей эффективности в целях её повышения
Образовательная программа	Менеджмент (Master in Management - MIM)
Направление подготовки	Менеджмент
Год	2020
Научный руководитель	Федотов Юрий Васильевич, к. э. н.
Описание цели, задач и основных результатов	Руководство КНР выдвинуло инициативу под названием "Пояс и Пути", направленную на активизацию экономического сотрудничества с Россией и европейскими странами. В последние годы российско-китайская торговля растет высокими темпами. Большое значение в этом процессе имеет логистика морских перевозок. По этой причине измерение эффективности и потенциала морских перевозок представляет собой актуальную задачу. Объектом исследования выступают контейнерные терминалы, задействованные в российско-китайской торговле. Цель данного исследования – измерение пропускной способности контейнерных терминалов, определение лучших практик среди рассматриваемых контейнерных терминалов, а также выявление потенциала повышения их пропускной способности. В работе используется пространственная выборка, включающая данные по 58 контейнерным терминалам РФ и КНР. Данные были получены с помощью анкетного опроса и открытых источников. Проведенное исследование показало, что основными показателями, определяющими пропускную способность контейнерного терминала, выступают общая площадь для складирования контейнеров, число причальных (седельных) кранов и сводный индекс масштаба терминала, интегрирующий характеристики длины и глубины причальной стенки. В результате использования методов анализа границ производственных возможностей (SFA и DEA) были получены оценки эффективности инфраструктуры выбранных терминалов с точки зрения обеспечения обработки существующего потока контейнеров. Полученные на основе SFA оценки эффективности имеют значения в диапазоне от 0,445 до 0,984. Последующее применение модели DEA позволило оценить потенциал повышения пропускной способности рассматриваемых контейнерных терминалов.
Ключевые слова	Инициатива "Пояс и Пути", контейнерные терминалы, пропускная способность контейнерного терминала, измерение эффективности, техническая эффективность, граница производственных возможностей, методы SFA и DEA.

ABSTRACT

Master Student's Name	Chen Shenglong
Master Thesis Title	The ‘Belt and Road Initiative’ container terminals’ throughput handling capacity: measurement of current performance in search for improvement
Educational Program	Master in Management - MIM
Main field of study	Management
Year	2020
Academic Advisor’s Name	Yury V. Fedotov, Associate Professor
Description of the goal, tasks and main results	The Chinese leadership has put forward an initiative named “The Belt and Road”, aimed at enhancing economic cooperation with Russia and European countries. Russian-Chinese trade has been growing rapidly in recent years. The logistics of maritime transportation is of great importance to this process. With this in mind, measuring the efficiency and potential of maritime transportation is an urgent and relevant task. The objects of research are container terminals involved in Russian-Chinese trade. The purpose of this study is to measure the throughput handling capacity of container terminals, to identify best practices among the selected container terminals, and to explore the potential for increasing their throughput handling capacity. Given research uses a spatial sample that includes data on 58 container terminals from the Russian Federation and China. The data was obtained with the help of questionnaires and open sources. The study revealed that the main indicators that determine the throughput handling capacity of a container terminal are the total area for storage of containers, the number of quay cranes, and a composite index of the terminal scale, which integrates the berth’s characteristics of the length and depth. Through the application of the production frontier analysis (SFA and DEA) methods, we calculated the efficiency scores for selected terminals in terms of ensuring that existing container flow is handled. The infrastructure efficiency scores based on SFA range from 0.445 to 0.984. The subsequent application of the DEA model allowed us to obtain the estimates of the potential for increasing the throughput handling capacity for the container terminals in the sample.
Keywords	The Belt and Road Initiative, container terminals, container terminals’ throughput handling capacity, efficiency measurement, technical efficiency, production frontier analysis, SFA and DEA methods.

Table of Contents

Introduction ……………………………………………………………….……………… 7

Chapter 1. Overview of port performance studies

1.1. Definition of throughput handling performance of container terminals…………….....…...10

1.2. Review of previous performance studies of container terminals …..…..……………………..13

1.2.1. Partial indicators methods ………………………………..…….……………………..13

1.2.2. Stochastic Frontier Analysis ………………………….……..……………………..15

1.2.3. Data Envelopment Analysis ………………..……..………..………………………..18

1.3. Summary of chapter 1 ……………………...…………………….………………………………21

Chapter 2. Description of the research context and research objectives

2.1. Sino-Russian trade ……………………………………………………….…………...………….23

2.1.1. The contemporary trade situation …………………………..….…..………………... 23

2.1.2. The opportunities and challenges to both countries ……….…..……………………….25

2.1.3. The prospects of future ……………………………………………………………26

2.2. The Belt and Road Initiative …………………...……………………………………………...27

2.2.1. The content of this new policy …………………………..………….....................27

2.2.2. The influence of it to both countries …………………………..….....................28

2.2.3. The future of the initiative Belt and Road ………………………………….….……..29

2.3. The contemporary situation of container terminals ………………….…………….…………….30

2.3.1. The importance of container terminals …………………………,…...……………30

2.3.2. The development of container terminals ………………………….………………32

2.4. Research objectives ……………………………………………„……......................33

2.4.1. Research gap ……………………………………………………………………33

2.4.2. Research objectives and questions………………………………„………………..35

2.5. Summary of chapter 2 ……………………………………………………………... 36

Chapter 3. The methodology of the study

3.1. The first stage….…………………………………………………………………….……...38

3.2. The second stage: Stochastic Frontier Analysis…….………………………………….………...39

3.3. The third stage: Data Envelopment Analysis…………………………………………………41

3.4. Summary of chapter 3 ……………………………...……………………………46

Chapter 4. The empirical study of container terminals

4.1. The first stage of the research……………………………….…………………….……… 48
4.2. Variables definition and Data description…………..…………..…………………….50
4.2.1. Variables definition……………………….……………….……………..50
4.2.2. Data description………………………………………….……………….52
4.3. Stochastic Frontier Analysis……………………………………………………….53
4.3.1. Regression analysis…………………………...…………………………...53
4.3.2. Principle components analysis……………….……………………………...56
4.3.3. Stochastic Frontier Analysis……………………...…………..………………...58
4.4. Data Envelopment Analysis……………………..…………………………………...60
4.5. Summary of chapter 4…………………………...………………………………….63

Conclusion **………………………………………………………….…….…….………65**
Reference **……………………………………………………….……….…………………...67**
Appendixes **…………………………………………………….……….…………………70**
Appendix 1: Questionnaire…………………………………………….…………………..70
Appendix 2: The efficiency score estimated by DEA……………………..………………….73
Appendix 3: List of figures……………………..………………………..…………………….75
Appendix 4: List of tables……………………………………………………….……………………76

Introduction

During the visit to Kazakhstan in 2013, Chinses president Xi Jinping has put forward an initiative named "The Belt and Road", aimed at enhancing economic cooperation with Eurasia countries. (Xinghua, 2013). China's Belt and Road Initiative (BRI), is a clear manifestation of the rise of the Chinese economy and a wish to cooperate friendly with the neighbors. It is, at its heart, a massive world-wide infrastructure project, reaching back into the heart of Europe. China has initiated $US1 trillion in projects, including roads, railways, ports and maritime routes to facilitate the new and revived trade corridors. (Howard, K. W., & Wu, J. 2015). When complete, the plan will incorporate countries that combined account for 60 percent of the world's population and one-third of its GDP.

Since the announcement of China's "The Belt and Road" initiative, more than 70 countries have already joined in this special activity. It encompasses the construction of a giant transportation system, including railways and highways, sea and air communications, power lines, and pipelines. These projects have the potential to become an engine of economic development for many Russian cities (Mikhail Magid, 2018). So many economics are interested in how this new initiative is going to develop and why Russia needs to maintain its place along with it.

On May 8, 2015, The People's Republic of China and the Russian Federation signed an agreement on the conjunction of the Silk Road Economic Belt. Russia and China are the two fastest-growing economies in the world. The fact is, there is a huge development happening in China and the relationship between Russia and China is very impressive, Sino-Russian trade has been increasing in recent years. What we have already known is that the BRICS emerging markets are fast developing in recent years, as two fastest-growing economies in the world, The People's Republic of China and the Russian Federation has been building a strong international relationship, the Sino-Russian trade volume is reaching a level, which is higher than any other historical record (Panibratov, A. 2017). Statistically, in the first 11 months of 2019, bilateral trade between China and Russia reached the US $100.32 billion, up 3.1 percent year on year. It is expected that the trade volume between China and Russia will exceed 110 billion US dollars in the next decade.

The International Monetary Fund (IMF) fully appreciates the importance of the "Belt and Road Initiative" for the global economy. Analysts believe that the scope of foreign investment from China alone in these infrastructure projects could reach $1 trillion over the next 10 years. So far, there are more than 70 countries included in the initiative, but this number could grow to 100 in the near future.

The world is pursuing the goal of economical sustainable development, the economic globalization has become the contemporary mainstream. In such a kind of background, the cross-border business has become the best option to promote national economic development. Within this international business communication, we could not ignore the significant roles played by international logistics. Those railway and maritime transportation are making sure that the international markets can operate stably. And maritime transportation, as the first choice for trading, should be paid more attention from scientific researchers.

International logistics must keep up with the progress of the economy. Among those logistical infrastructures, maritime transportation is the favourite choice and occupied more than half of the total international trade volume. The seaport and terminals are the basic elements of building ties for international cooperation. Only the operation of those international seaports can be guaranteed, cross-border economic cooperation could be realized.

Since the growing demand for maritime traffic significantly intensifies the competition among seaports, especially for container terminals, the performance measurement of them is attracting more and more attention from researchers and business managers. Considering foreseeable prosperity in international trade and gradually fiercer competition among those international ports, the efficiency measurement and performance improvement of them have become an important task worth to be researched. To improve the competitiveness and performance, international seaports and terminals have to improve their cargo throughput handling capacity.

Based on the background of the special political proposal, the given research has described the contemporary trade situation of Sino-Russian as a representative part of the initiative "Belt and Road", highlighted the performance of maritime logistics. As the most popular operation units in maritime transportation, the container terminals can be chosen as the representative research objects. As we know, many research works have been done to measure the performance of seaports and terminals. However, there still exist some research gaps. At first, most of the current studies have not considered the impact of the specific economic context of the Sino-Russian strategical relationship or considered the special context of the Belt and Road Initiative. Next, lots of research works concentrated only on the overall performance measurement, there is no study which measured the container throughput handling capacity. Last, the previous researches do not figure out what kind of factors that the terminal authorities truly need to care about. No research identified the attributes of throughput handling capacity and further explore the potential for improvement.

The previous research conclusions may not apply to current Sino-Russian conditions, and difficulty in the improvement of terminals' performance within the "New Silk Road" exists. The research in this area is worth conducting. There are still needs in assessment of the current throughput performance of the container terminals related to the “Belt and Road Initiative” and the potential to improve the performance of the container terminals involved in implementation of the “Belt and Road Initiative”

The subject of the given research is the measurement of the container terminals’ throughput handling performance and research objects are Chinese and Russian container terminals involved in the “Belt and Road Initiative”. The core part of the given research is the investigation of Sino-Russian container terminals’ throughput handling capacity measurement, furthermore achieve the goal of the research, which is to evaluate the potential to improve the seaport container terminals’ throughput performance. The research objectives could be list as:

- To identify the influencing factors of container terminals’ throughput performance.
- To determine the best practices within the Chinese-Russian container terminals industry.
- To measure the technical efficiency of container terminals from the chosen sample and provide suggestions for performance improvement.

Finally, the research conclusion would be used to indicate the terminals’ current throughput handling performance, obtained through the benchmarking approach, analysing the cross-sectional data from representation container terminals involved in Sino-Russian maritime trade. Through this study, the selected sample container terminals can find their status in the Sino-Russian trade because the measurement results might be referred to as performance monitoring. With the result of the study, the managers can also know which factors may affect their throughput handling capacity and thus pay more attention to them to get the promotion.

Chapter 1. Overview of port performance studies

1.1. Definition of throughput handling performance of container terminals

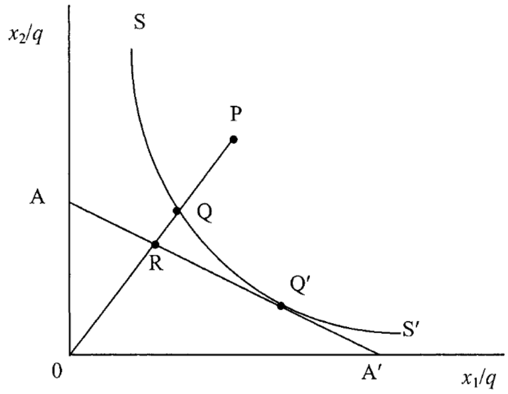
To conduct the performance measurement research, it is necessary to define the terminals' container throughput handling performance at first. As the subject of the given research, the measurement of the container terminals' throughput handling performance measurement is different with other kinds of performance measurement. The throughput handling capacity of container terminals is a more specific indicator than the overall performance. It considers more about how many containers arrive at their destinations and further delivered successfully. Because of this, the input factors that should be selected in the study should also be restricted accordingly.

For the most part, throughput handling performance is measured through calculating the operational efficiency of container terminals, which is measuring how much terminal's facilities and equipment, such as the number of containers delivering machine or the storage area, were used and how much the container's flow was handled successfully in a certain period of time. When a company engages in the production, it is concerned with the problem of translating the multiple inputs into multiple outputs. In reality it rarely happens where only single inputs and single outputs, therefore in the given research we will not considering such a situation.

As for the operational efficiency of a firm, theoretically, the situation where it is possible with the given technology, to produce a larger output from the same inputs, or the same output with less of one or more inputs without increasing the number of other inputs. In such cases, we could say that firm is in a situation of operational inefficiency. On the contrast, in the situation where the firm could not increase outputs without change the consumption of inputs, or when firm decreases the expense of one or more inputs without reducing the number of other inputs, the outputs will decrease immediately, we could say that the firm's production was technical efficiently.

In other words, we can explain the efficiency through the graph of the production function frontier (Farrell 1957). In this way, we can figure out how can a firm increase its output production by improving its efficiency, given the same level of resource consumption. And in this model two types of efficiency can be distinguished: technical efficiency and allocative efficiency. If the company achieved both those two efficiencies, which will mean that the company has fully economic efficiency. Farrell proposed that efficiency always consists of two components: technical and allocative efficiencies. Technical efficiency refers to the ability of the firm to convert a set of inputs into a maximum of output, whereas allocative efficiency represents the ability to use the inputs in optimal proportions (Farrell 1957). The combination of these two variables provides a measure of total economic efficiency, which can be explained in the graph below.

Figure 1: The production function frontier (Farrell 1957)



In this graph, the measurement of efficiency can be explained by the distance of several relevant points. At first, we assume that the firm has used two inputs (X_1 and X_2) to produce a single output (q), and in this example, constant returns to scale precondition is assumed, which allows the technology to be represented using the unit isoquant curve (production function curve) SS'. In this example, the measurement of efficiency will be shown as the distance of one statistic point P to the fully efficient production line SS'. (the production frontier of fully efficient firms is estimated from observations on a sample of firms in the respective industry). If the investigating company has the required inputs, which can be represented by X_1 and X_2 and determined by the point P, then the distance |QP| represents the technical inefficiency of the given company. This is the quantity by which the different inputs can be reduced without a decline of the output. The percentage of consumed inputs can be reduced and make sure to keep the volume of outputs can be expressed as the ratio: $\frac{|QP|}{|OP|}$, shows us how much the given company can reduce its consumption of inputs could still achieve the technically efficient production. And in this case, the technical efficiency of the company can be shown as:

$$\mathrm{TE} = 1 - \frac{|\mathrm{QP}|}{|\mathrm{OP}|} = \frac{|\mathrm{OQ}|}{|\mathrm{OP}|}$$

The value of the TE lies between 0 to 1, giving us information about how efficiently is the company’s production. When the value of TE infinitely close to 1, which shows the company is fully technical efficient. For instance, the point Q’ lies on the unit isoquant curve of SS’, which means at this point, the company is technically efficient in production.

In Farrell’s figure, the direct line of AA’ represents the iso-cost, its slope equals to the ratio of prices of two inputs X_1 and X_2. The intersection of AA’ and SS’ in the point Q’ represents the optimal production situation, where the two inputs are in an optimal consumption ratio, which means keep the level of production, the consumption cost of two inputs can reach the minimum value. In this case, the company's production is allocative efficient. A more precise definition of allocative efficiency is at a specific output level where the Price equals the Marginal Cost (MC) of production. This is because the price that consumers are willing to pay is equivalent to the marginal utility that they get. Therefore, the optimal distribution is achieved when the marginal utility of the good equals the marginal cost.

However, the production point Q' is not available for the firm, because it is not lying on the company's real production line. the achievable plan for the company should be found on the direct line OP. Based on the technical efficiency, furthermore, the company can find its allocative efficiency point R, the intersection of AA' and OP.

The allocative efficiency could be defined as:

$$\mathrm{AE} = \frac{|\mathrm{OR}|}{|\mathrm{OQ}|}$$

In the conclusion of this case, the ratio of $\frac{|\mathrm{OR}|}{|\mathrm{OP}|}$ can represent the full efficiency of the given company's production, both the technical and allocative efficiencies can be explained by the movement of production point: from point P to Q, which is technical efficiency, the company can achieve this by changing the production technology. From point Q to Q' is a company searching for optimal inputs consumption, which can be achieved by changing the combination of inputs. But the production plan of point Q' cannot happen because it is not lying on the production curve of OP, so the injection of curves AA' and OP, which is point R can represent in this case for the optimal combination and at the same time, it is an achievable production plan. The ratio $\frac{|\mathrm{OR}|}{|\mathrm{OP}|}$ is called the overall efficiency of the firm.

Besides the methodology we have discussed above, the conception of technical efficiency can be understood not only as "seeking for the maximum outputs using required inputs", respectively, it can also be explained still as input-oriented. The technical efficiency can still reflect the ability of a firm to reduce the input given the same level of output (Coelli, Prasada Rao and Battese 1998).

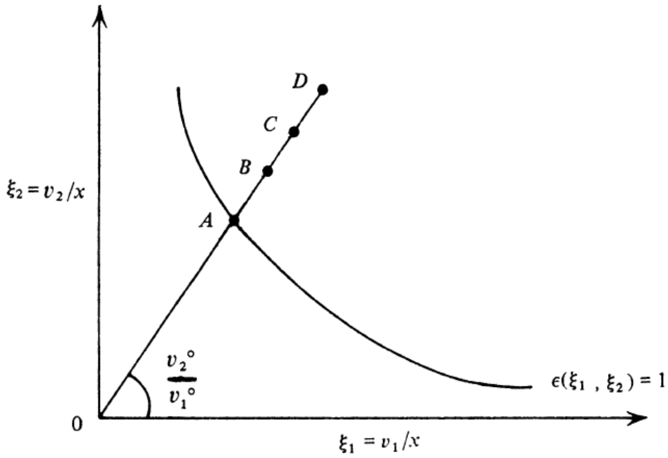
There exists another efficiency measurement, which shows the level of how close a given company is to the optimal scale (Forsund and Hjalmarsson 1979), scale efficiency refers to the ratio of productivity measured when the firm produced at the ideal level, in other words, to the optimal scale. The production function form can be shown as:

$$v = \mathrm{F}\left(\frac{v}{x}\mathrm{x}\right) = \mathrm{F}(\xi\mathrm{x})$$

where x represents inputs, v is output, ξ is input coefficients.

From this statement, it assumes that efficiency frontier is a set of points and it has production subset, where the input coefficients $(\xi_1, .., \xi_n)$ obtain their minimum values. The figure below can display how an observed company can change the scale of inputs but keeping the same level of output.

Figure 2: The efficiency frontier (Forsund and Hjalmarsson 1979)



Therefore, we have defined three types of operational efficiency. Allocative efficiency differs from technical and scale efficiencies in that the former addresses issues such as costs or profits, depending on the different combinations of inputs, whereas the other type of efficiencies only considers physical quantities of outputs and technical production environments. Since in this research we consider solely non-financial data, only technical and scale efficiencies are examined in depth.

1.2. Review of previous performance studies of container terminals

Based on the facts we discussed above, the throughput handling performance measurement of container terminals became an essential concern, the efficiency of the whole supply chain depends on the efficiency of ports and container terminals, the gradual increasing competition among them also underlines the importance of performance measurement and improvement. A lot of researchers have already noticed that and have made several relevant studies. All these methods for measuring the performance of seaports can be sorted into two main categories. The first category consists of partial productivity indicators in the port industry. The second category includes more quantitative methods, such as Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA), these quantitative methods were introduced by former researchers and are widely used to measure overall industry efficiency.

1.2.1. Partial indicators methods

Through this method, the port's performance was measured by using a variety of partial indicators. The examples of frequently used estimates are calculating cargo-handling productivity at berth (Bendall and Stent 1987; Tabernacle 1995; Ashar 1997; Framkel 1991), measuring single factor productivity (De Monie 1987) or comparing actual with optimum throughput over a specific period (Tally 1998). Moreover, numerous port authorities publish their annual reports in the form of partial indicators. What should be mentioned here is that a lot of attention has been paid only on the financial indicators for the accounting system. But such kind of information is not enough sufficient for performance measurement in the maritime industry. Performance measures must go beyond the presentation of financial figures and serve as the driver for fostering performance not only in financial terms but also in non-financial aspects like quality, customer satisfaction, innovation, and market share (Kwai-Sang China, Kit-Fai Punb, Henry Lauc, 2003).

The method of partial indicators was applied by Talley (1994) and Tongzon (1995) to compare different ports for the first time. They managed to measure and compare the performance efficiency of selected objective ports, using comparable indicators and controlling related variables at a similar level. Further research to study the inter-port competition through comparison of a set of representative productive indicators among ports was carried out by Heaver (1995) and the Australian Productivity Commission (1998), the partial indicators methods had contributed to the research.

In 1976 the UNCTAD had proposed the port performance indicators as shown in the table below, underlie that productivity and effectiveness can be utilized as a reference point for the multiplicity of measurement. Each of these partial indicators represents one specific feature of the company's performance.

Table 1: Summary of performance indicators suggested by UNCTAD (1976)

Financial indicators	**Operational indicators**
Tonnage worked	Arrival lateness
Berth occupancy revenue per ton of cargo	Waiting time
Cargo handling revenue per ton of cargo	Service time
Labour expenditure	Turn-around time
Capital equipment expenditure per ton of cargo	Tonnage per ship
Contribution per ton of cargo	The fraction of time berthed ships worked
Total contribution	Number of gangs employed per ship per shift
	Tons per ship-hour in port
	Tons per ship hour at berth
	Tons per gang hours
	The fraction of time gangs idle

Even though partial productivity approach can be seen as a useful tool for comparing and measuring certain aspects of ports performance, the main limitation of the given method is its partial view which does not yield an analytically consistent approach to the joint contribution of the various inputs to overall performance (Estache, Gonzalez and Trujillo 2002). The company's performance shouldn't be estimated by only a simple reference score. For instance, although a container terminal can be very efficient in terms of the container handling rate (TEU/Hour), this does not powerfully mean that this container terminal utilizes all inputs efficiently to produce output. It is still possible that other inputs are used inefficiently or the company behaves negatively. These facts will decrease the overall efficiency level of this container terminal (Heng, 2003). Therefore, the revelation of partial indicators method can be a truly limited and overall evaluation of port performance cannot be achieved.

The growing demand for an approach to obtain the general performance estimate for ports has resulted in the application of more quantitative methods, such as Stochastic Frontier Analysis and Data Envelopment Analysis. The preferences of the methods adopted in seaport performance research are almost evenly distributed between DEA and SFA, which are the representatives of the parametric method and non-parametric method respectively. The literature applying these two techniques to address port efficiency will be reviewed in the next two subsections.

1.2.2. Stochastic Frontier Analysis

At the earliest, Aigner, Lovell and Schmidt (1977), Meeusen and van den Broeck (1977) independently presented a new methodology of efficiency evaluation, Stochastic Frontier Analysis (SFA), which highlighted the existence of non-negative statistic error. In their research works first introduced the SFA method, using econometric techniques where efficiency is measured relative to a statistically estimated frontier production function.

Liu (1995) applied the SFA to test the hypothesis that the ownership of the ports can significantly influence operation efficiency. This is the first time that ownership was suggested as a potential factor in the frontier production function. The data for the analysis represented the observations of 28 main commercial UK ports over the period from 1983 to 1990. Besides, the author still used the regression method. The results of this study revealed that the efficiency difference between ports in the public sector and the private sector was insignificant and negligible. Moreover, he also found that the capital intensity and the port size can have a small correlation with the ports' efficiency.

Coto, Banos, and Rodriguez (2000) first applied the Cobb-Douglas and Translog versions of the mathematical form in the SFA model building. The researchers collected a panel of data of

27 Spanish ports from 1985-1989, to evaluate the economic efficiency. The comparison of the two versions revealed that the Translog version better represents the level of ports' technology because the cross-relationship of different independent variables was considered. Furthermore, the model had also shown that the port size is significant when explaining the economic efficiency and the degree of autonomy in the port management is found to be the critical factor: the higher the degree of autonomy, the more the efficiency.

In the study of Notteboom, Coeck and van den Broech (2000) the comparative analysis of different ports and terminals is separated the first time. Using the SFA model to estimate the productive efficiency of a set of 36 European container terminals located in the Hamburg-Le Havre range and the Western Mediterranean in 1994, supplemented with four benchmark container terminals in Asia. Their work revealed that small size container terminals tend to be less efficient than large ones, and those small terminals located in large ports have higher efficiency scores than small terminals located in small ports. Besides these, they have found that the formidable intra-port competition can have a positive effect on the productive efficiency of container terminals within the port.

In the year 1993, the Mexico has carried out a reform in the port industry. Estache, Gonzalez, and Trujillo (2002) examined the effects of it by conducting two stochastic production frontier functions, the Cobb-Douglas and the Translog. The data covers observations of 14 Mexican ports from 1996 to 1999. They used capital (the length of docks) and labour (the number of workers) as the input variables, and the total volume handled at terminals as the dependent variable. The main conclusion is that the reform of decentralization and privatization taken at Mexico's ports has generated large short-term improvements in the average performance of the ports.

Cullinane and Song (2003) estimated the effect of Korea's port privatization policies. The independent variable, in this case, is the level of the privatization of the container terminals. The main finding is that productive efficiency has a positive relationship with the degree of private sector involvement and has improved since the implementation of privatization and deregulation reforms in the Korean port industry.

Gonzalez and Trujillo (2008) estimated the effect of the 1990's port reforms on the evolution of technical efficiency in port infrastructure service providers in the major Spanish port. The data covered the 17 major commercial ports of the country and captured a broad typology of ports, including insular ports, hub ports, and different specializations (e.g. in liquid bulks, in dry bulks, etc.), for 1990-2002. The researchers used three variables representing the port output (cargo, passengers, and charges) and three inputs (work, berths, and area) To describe port technology. What should be mentioned here is that the researchers had considered the first time the effect of the geographic location of ports (mainland or island ports) and the refineries near the port on efficiency.

Liu (2010) had focused on the efficiency estimation of ports and terminals and has measured the impact of exogenous variables, such as trading volume, terminal operator type (either local or global operator) and terminal type (either container or multi-purpose terminal). He used two datasets: a panel dataset for 32 container terminals in the North Mediterranean Sea over nine years (from 1989 to 2006), and a cross-sectional dataset for 165 container terminals worldwide. Some interesting new findings were also provided by the researchers, such as trading volume plays a key role in the operation efficiency; container terminals are proven to be more productive than multiple purpose terminals; global terminal operators were not proven to out-perform local terminal operators; the container terminal operation industry is over-scaled.

Using data collected from 25 Brazilian port terminals, Wanke, P. F., Barbastefano, R. G., & Hijjar, M. F. (2011) studied operational performance with the SFA model. The researchers found out the influence that comes from capital is important to port efficiency. Due to a lack of investment and export boom, the conducted results revealed that the majority of the ports were running inefficiency.

In the research of Bergantino, A. S., Musso, E., & Porcelli, F. (2013), they have mentioned the importance of considering contextual variables to measure the ports' performance. Using the SFA model to carry out through fixed-effect estimators, and the sample was composed with 30 ports observed.

Tovar, B., & Rodríguez-Déniz, H. (2015) introduced to us in their research the research gap of port classification while measuring their performance. They have used a mixed methodology, SFA model building was included, to figure out the function of specific clusters. To achieve the improvement goal, the managers need to group ports into performance metrics' categories. And the result of the research offered useful information about the port industry's reform to decision-makers.

Perez, I., Trujillo, L., & González, M. M. (2016) tried to further figure out the efficiency determinants of ports in their research. The main objectives were the reform and modernization among ports in Latin American. Whether the modernization of ports can result in increased efficiency and which factors are currently influencing container terminals' efficiency. The result of conducting the SFA model showed an average level of efficiency of 83%, which revealed a positive effect of modernization and there was still space for improvement.

Wiegmans, B., & Witte, P. (2017) focused on the inland waterway container terminals' performance measurement, besides deep-sea container terminals. Since the ports with different locations have different combinations of inputs, the efficiency could be different, the same as the influence of individual factors. In their study, the inputs used were yard, crane, terminal operating hours and terminal area. The interesting point that comes from the SFA model is that the operating hours can be seen as a special input for IWTs which is different from maritime terminals, which are open 24/7.

Nguyen, H. O., Nghiem, H. S., & Chang, Y. T. (2018) conducted a case study of Vietnamese ports. The researchers wanted to prove that, the seaports in different groups operate under different technologies. So, the influence of each input should be treated separately. The sample of 43 ports in Vietnam is divided into groups and the SFA model was built. The result showed that the land is important for the efficiency of ports in the North, whereas the cargo storage capacity to ports in the central areas, and information technology is important to ports in the North. Besides, the SFA model in this article also revealed, which inputs could be decreased while keeping the level of outputs.

1.2.3. Data Envelopment Analysis

Differentiate from SFA, DEA has the advantage of multiple outputs and inputs, which accords with the operating characteristics in the seaports industry and makes it possible to provide an overall estimation of port performance through a comparison with a related frontier. Data envelopment analysis conducting comparative analysis through building a non-parametric model using data collected. The conception of this method was advocated by Farrell (1957), but only a few academics paid attention to this paper in the following two decades, this methodology did not receive wide attention until the paper by Charnes, Cooper, and Rhodes (1978), in which the term Data Envelopment Analysis was first used.

The first application of the DEA method in the port industry to measure port efficiency was proposed by Roll and Hayuth (1993). They proposed that seaports are complex service organizations thus difficult to measure efficiency through partial indicators or parametric methods. The researchers should think about a long list of outputs and inputs characterizing the operations of ports.

In the paper of Roll and Hayuth (1993), the advantages of the usage of the DEA model in seaports efficiency measurement had been highlighted. There are several advantages compared with traditional approaches, for instance, it enables consistent analysis of multiple inputs and multiple outputs. Besides this, the DEA model allows the inclusion of environmental, geographical location and other qualitative factors, which are highly important to conduct an overall evaluation of ports' performance. Moreover, through the result of DEA, the researchers can also recognize the possibility of different but equally efficient combinations of outputs and inputs (in different proportions). Comparing with regression models, DEA is a non-parametric method, which doesn't require a specific relationship among those variables and weights for the various factors.

Investigating 26 Spanish ports with 5 observations for each port, Martinez et al. (1999) examined relative efficiency with the help of the DEA model. The data for the 5-year (1993-1997) period allowed them to make a comparison among the ports over time. In his paper, the influence of the economies of scale had been proposed to think of and the researchers pointed out that the port activity should exhibit increasing economies of scale given the importance of fixed costs. Choosing one of the basic models of the DEA method, the BCC model (Banker, Charnes and Cooper 1984), helped authors take into consideration the economies of scale.

Also, the author divided all the ports into different homogeneous categories according to the complexity criteria given by the port size. As a result of the study, the authors concluded that the ports with higher complexity are associated with higher efficiency and have gone closer to the frontier during the time. And the group of ports smaller complexity demonstrated even negative value of efficiency.

Noticing that those ports are a significant part of the international trading chain, and, logically, we should evaluate the performance not only among the domestic market but compare them at the international level. Based on this fact, Tongzon (2001) extended the measurement problem of port efficiency to an international level by applying the DEA method to conduct an international comparison of port efficiency among 4 Australian and 12 other international container terminals for the year 1996. The author used two outputs and six inputs in the evaluation model. The two outputs are the total throughput handled per year in terms of TEU and the number of containers moved per working hour per ship. The six inputs are the number of berth, cranes, and tugs representing the capital input, the terminal area of ports as the land inputs, and the number of employees as the labour input, the amount of delay time, indicating usage efficiency of time.

To solve the problem with the port's ownership, Valentine and Gray (2001) conducted DEA analysis about port efficiency with the particular types of ownership structures, applying the DEA-CCR model to 31 container terminals out of the world's top 100 container terminals for the year 1998. The number of containers and total tons throughput is defined as outputs to show the ports' productivity, while whilst the total length of berths and container berth length is chosen as input variables. In their work, the most efficient ownership structure is found to be joint private/private, followed by private ports and lastly publicly owned ports.

In 2003 some researchers noticed that the governance structure may influence the efficiency of the ports. Barros (2003) made use of data about 5 Portuguese ports in 1999 and 2000 to conduct a DEA analysis. The conclusion of his research tends out that, incentive regulation carried out by the government regulatory body or the Maritime Port Agency, has not managed to enhance the efficiency of the ports.

Turner, Windle, and Dresner (2004) started to be interested in the previous research that the existence of economies of scale in the ports industry. Thus, they applied DEA to define the changes in infrastructure productivity in 26 North American ports over the period 1984–1997. The inputs were total terminal land dedicated to container operations, total quayside container gantry cranes, and total container berth length. And they use the total twenty-foot equivalent units handled to measure the output. It tends out that there are significant economies of scale present within the North American sector, both at the port and terminal level, given the huge fixed cost in the port industry.

Cullinane and Wang (2005) applied DEA CCR and BCC to measure the efficiency of a sample consisting of 69 Europe’s container terminals with annual throughput of over 10,000 twenty-foot equivalent units (TEUs), which in their study are seen as large size terminals. The authors used cross-sectional data for 2002 from 24 European countries. Container throughput is used as terminal output. The total quay length, the terminal area, the number of gantry cranes, the number of yard gantry cranes and the number of straddle carriers are incorporated into the models as input variables. The finding from their research is that the large container terminals almost operated with higher efficiency, the reason behind this could be the variable increasing return to scale.

It occurred to Wu, J., Yan, H., & Liu, J. (2010) the importance of investigation about the individual input or output, measure their specific impact on the ports’ efficiency. They applied the DEA model to test the sensitivity of the individual input and output of a DMU. And the conclusion showed us that the number of the berth and the capital deployed are the most sensitive factors impacting performance.

In 2012 some researchers tried to fill the gap of cargo type problems, noticing that the previous port efficiency studies have almost focused on container terminals. Merk and Dang (2012) distinguished world ports by cargo type (containers, oil, coal, iron ore, and grain) and used databases consisted of approximately 100 ports. The researchers applied DEA CCR and BCC methods to figure out the relationship between cargo type and operation efficiency of the ports. They identified that among different cargo types container and oil terminals use technology more efficiently than other types of terminals.

Merk and Dang (2012) also identified the relationship between the size of port and efficiency. The crude oil, iron-ore and grain ports have higher efficiency scores at a larger total port size, suggesting that larger size is more efficient in operation.

Furthermore, Shui-Mu Ju & Nan Liu (2015) conducted DEA research to investigate the relationship of various inputs with efficiency. Results showed that long term or short term, the ratio of state-owned shares, debt asset ratio, and operating costs ratio are negatively related to efficiency. Conversely, ports size, the ratio of outside directors, and human capital are positively related to efficiency.

In the research of Nguyen, H. O., Nguyen, H. V., Chang, Y. T., Chin, A. T., & Tongzon, J. (2016), considering the sensitivity to the number of variables of standard DEA model, three different methods were used and their results, efficiency scores were compared. The conclusion proved the existence of difference among the results of bootstrapped DEA, standard DEA, and SFA. While the scores obtained from bootstrapped DEA was more reliable, efficiency scores produced by standard DEA and SFA were much larger than bootstrapped DEA.

With the continuous economical glory, the researchers have noticed that the efficiency measurement of the ports should not only relate to their productivity, but the environmental factors should also be considered as well. Sun, J., Yuan, Y., Yang, R., Ji, X., & Wu, J. (2017) proposed that environmental protection and operational efficiency have the same importance for the port firms. Building the DEA model, the study revealed that when environmental factors are considered, the average efficiency of all selected ports tends to be lower. The port assets, berth quantity, and the geographical location can significantly impact the environmental performance of those Chinese ports' efficiency.

After the reform of the modernization of ports, the recent research started to concentrate on the automated ports efficiency measurement. XU, Y., & ISHIGURO, K. (2019) conducted an SFA analysis to measure the Efficiency of Automated Container Terminals in China and Korea, comparing with traditional terminals, using DEA model. The following six variables were used in the research as inputs: water depth, quay length, storage area, number of quay cranes, number of gantry cranes, and number of terminal transfer vehicles. Container throughput is considered as the output. Even though the result didn't show significant superiority of automated terminals, but there existed a clear efficiency contribution from automated inputs.

1.3. Summary of chapter 1

With the fast-growing of the international economy, various types of companies have played different roles in this process, the performance measurement and improvement of them have become an academic research hotspot. The usage of different research methodologies has also theoretical significance for scientific research. In this process of business globalization, international logistics are in a unique position. In such a good economic situation, the growing demand for maritime traffic significantly intensifies the competition among seaports, especially for the container terminals. To improve the competitiveness and accommodate growing container traffic needs, ports and terminals have to improve their container throughput handling capacity. Only in this way the promotion of logistics service companies can be achieved, which furthermore promote international business development.

In this chapter, we have introduced the definition of container throughput handling performance measurement and the methodologies to measure operational units' efficiency. The previous research works concerning the performance measurement of container terminals are listed and three different techniques, which are used in performance researches are explained in this chapter, the advantages and drawbacks are all declined and compared.

In the further research chapter, the focus will be on the current throughput handling performance measurement of container terminals, benchmarking the best practices of chosen research objects, to identify the factors which affected the performance and find the potential for improvement. The expected findings of the research are supposed to show the measurement of existing container terminals and find the factors which affect their container throughput handling capacity. The expected findings might, for instance, help in decision improving the productivity of international logistics. They can help companies to find out the way for improvement.

Chapter 2. Description of the research context and research questions

2.1. Sino-Russian trade

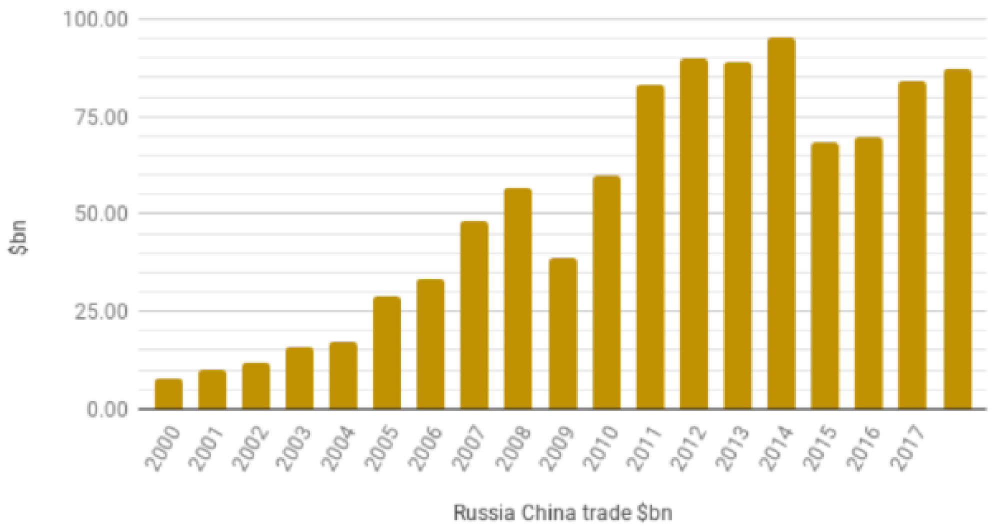
2.1.1. The contemporary trade situation

China and Russia have always been important trade partners. The recent decade was a period in which continuous trade and growth have been seen for both sides. In the first 11 months of 2019, bilateral trade between China and Russia reached $100.32 billion, up 3.1 percent year on year. It is expected that the trade volume between China and Russia will exceed 110 billion US dollars shortly. Even some Russian economists say that the trade volume between China and Russia is expected to reach 200 billion US dollars by the year 2024. With an upgrade in the strategic cooperation between China and Russia, a huge opportunity for growth is continuous existing. This will continue and is going to be a mainstream of the future world. (Panibratov, A. 2017).

On May 8, 2015, Russia and China signed an agreement on the conjunction of the Eurasian Economic Union and The initiative Belt and Road, both states are getting closer and closer – with transport and logistics play a key role in bringing each state together. Which also means an increasing demand for cross-border logistics services and operations. Against the background of difficult relations with the west at the time of writing, Russia is very interested in widening and strengthening the cooperation with China and building a long-term sustainable partnership (oglu Nasirov, A. Y. (2018).

China is Russia's second-biggest export market and the biggest source of import. Trade turnover between Russia and China was up by more than a quarter (28.2%) in the first ten months of the year 2018 to $87.2bn. And in the year 2019, imports and exports between China and Russia total 88.4 billion USD, growing by 29.4%. While In 2016, trade turnover between China and Russia grew by 2.2% and reached $69.52bn. In 2017, it increased by 20.8% to $84.07bn.

Figure 3: The Sino-Russian trade volume (bne IntelliNews, 2018)



The two countries set a target to hit $100bn of trade turnover a few years ago, but that was stymied by the "silent crisis" years of 2014-2016 that hurt both their economies. However, if the trade continues to expand at the same pace as expected, trade turnover should achieve to $150bn by the end of this year. What should be mentioned is that recently Russian President Vladimir Putin and China's President Xi Jinping set a new goal of $200bn by 2024 and at the current rate of expansion this looks entirely achievable. Compare with the collapse of the Soviet Union in 1991 the mutual trade turnover was a bit less than $5bn, an earth-shaking change is happening.

At this time, Russian Prime Minister Dmitry Medvedev reiterated the new $200bn goal for bilateral trade between Russia and China. At a press conference after the 23rd regular meeting between the Russian and Chinese government heads the minister said: "Bilateral trade is actively developing, and this year we will approach the level of $100bn, which seemed fantastic to us 10 years ago; now we are speaking about other levels, about the possibility of reaching $200bn of trade turnover, and I believe this figure to be quite realizable for our countries if we actively promote cooperation in the agreed spheres"

Besides, Russia is beginning to diversify its exports to China from just supplying oil and gas. (Paik, K. W. 2015).

"We see ties expanding on traditional goods, such as timber, metals, chemistry and the like, agricultural trade has risen 1.5-fold since the beginning of the year. Green cosmetics and children's goods are becoming increasingly popular. A big number of energy and high-tech projects are being implemented. There are agreements regarding a joint project on heavy helicopters, cooperation is developing in space and energy fields," Medvedev added.

Russian imports from China mainly consist of electronics, textiles, and metals, with a total value of 23.47 billion USD, 4.92 billion USD, and 3.98 billion USD respectively, taking up 46.2%, 9.7%, and 7.8% of total Russian imports from China. Food, beverages, and tobacco have seen a significant increase by 15.9% while light industrial products such as shoes, boots, and umbrellas have seen a decrease of 22.1%.

However, energy remains important. In 2017, Russia became the largest oil supplier to China. (Bolt, P. J., & Cross, S. N. 2010). Work is underway to increase the capacity of the Sino-Russian oil pipeline, the construction of a gal pipeline continues according to schedule.

China is also an investor in the Russian project to build a new LNG gas plant on Russia's Yamal Peninsula. The plant's first phase went online earlier this year and a second phase is planned.

Russia and China are also cooperating on nuclear energy. On July 8, the two countries signed seven documents that included a framework contract on the construction of the seventh and eighth units of the "Tianwan" Nuclear Power Plant, a contract for the construction of the

VVER-1000 water-power reactors at a new Chinese facility and an intergovernmental agreement on the construction of a CFR-600 demonstration fast neutron reactor in China.

2.1.2. The opportunities and challenges to both counties

Opportunities:

Since the collapse of Russia's relationship with the West over Ukraine, the Sino-Russian strategic partnership has become more of a reality. Russia and China share a common desire to challenge the principles of the Western-dominated international system. As a result, bilateral ties between the two countries have become highly personalized with Russian President Vladimir Putin and Chinese President Xi Jinping directing government commissions, sitting officials, and heads of state corporations to develop financial and trade deals—most of which are large-scale, top-down investments of Chinese money into key sectors of the Russian economy. (Pirchner Jr, H. 2008). Many areas like transportation infrastructure, energy, telecommunications, and high-tech military sales, Russia and China are now cooperating whole heartily.

At the 15th Saint- Petersburg international economy BBS, China, and Russia have set the goal of increasing bilateral trade to $100 billion before 2015 and reaches to $200 billion by the year 2020, which looks entirely achievable at the current rate of development. China's expanding commercial interests in Central Asia, the Russian Far East, and the Arctic are likely to increase the competitiveness of Chinese firms on a global scale.

In this case, Russia can consolidate its position as a major transit country and become a full Eurasian bridge in Sino-European trade between the east and west, the return on investment in transport infrastructure will result in the active development in many regions of the Asian part of Russia, making them more attractive for living and production. For Russia in general, the cooperation will dramatically enhance the MNE (multinational enterprises) revenue. (Lain, S. 2015).

Challenges:

The first is the economic model and political transformation. Economical trade activities are inevitably restricted by the political environment. In the early 1990s, the failure of the neoliberal economic system in Russia led to a decade of economic chaos and state decline in Russia. Under the guidance of the president and minister of Russia, dreaming of great power reconstruction, large enterprises with a dominant state status are gradually integrating and annexing other non-state enterprises, and the nationalization trend of Russia and Russia has become irreversible. How to adapt to this economic transformation and grasp the opportunity is the first concern of China's trade with Russia. (Bjelakovic, N. 2010).

Secondly, the challenges come from a competitive environment. After the collapse of the Soviet Union, China once dominated the Russian market due to its unique geographical advantages and cheap goods. However, with the recovery of Russian local enterprises and the diversification of the consumer market, the characteristics of Russia as China's consumer market have been repeated. Western developed countries are seizing the Russian market with their advanced marketing methods, abundant funds, high-quality products, and appropriate prices while emerging industrial countries are not willing to lag. Brazil, South Korea, and other countries are also actively competing with Chinese products with high quality and low price to occupy the Russian market. Under the situation of increasing original competitors and potential foreign entrants, the advantages of traditional Chinese industries and their marketing methods in the Russian market have weakened and they are facing major challenges. (Yeung, C. 2010).

Finally, the challenges of trade structure transformation between China and Russia. At the 15th Saint- Petersburg international economy BBS, China, and Russia have set the goal of increasing bilateral trade to $100 billion before 2015 and reaches to $200 billion by the year 2020. The target is exciting for investors on both sides, but for China and Russia, this number is out of proportion to the status of the two giants. For many years, Sino-Russia trade has been short of support from commodity exchange and high-tech products. The Russian government is reluctant to see the constant increase in the proportion of Russian energy products export. In this mindset, the Russian government has imposed more and more restrictions on Chinese light industrial products, which has affected the rapid growth of total trade between the two countries. To realize the rapid growth of Sino-Russian trade, China and Russia cannot only be limited to the simple exchange mode of the "light industry for energy", but also need to strengthen cooperation in other fields. Therefore, the pace of trade structure transformation must be accelerated. (Roh, K. D. 2019).

2.1.3. The prospects of future

Today, Russia can give its strategic partnership with China a qualitatively new economic content. The traditional factors of China’s interest for Russia (it is in the interests of China’s modernization to have good neighbours relations with Russia, and Russia has a large market for Chinese goods that are in low demand elsewhere) are now complemented by a new component: China has been reinforcing its positions as a global player, and Russia can provide leverage in relations with the United States and other powers. Besides, Russia’s resources are a natural advantage that can be used to balance out the structure of its economic relations with China through sound financial and investment policies. (Roh, K. D. 2019). Meanwhile, Russia’s tensions with several Western countries make Beijing more valuable for Moscow than vice versa.

China is a major player in the emerging markets, consequently a competitor of Russia. It is, thus, important to minimize any losses that could result from this rivalry by transforming competition into cooperation – initially, concerning Russia’s resources, and subsequently concerning the investment and innovation-based model of Russian Chinese trade and economic interactions. (Cross, S. N. 2010).

2.2. The Belt and Road Initiative

2.2.1 The content of this new policy

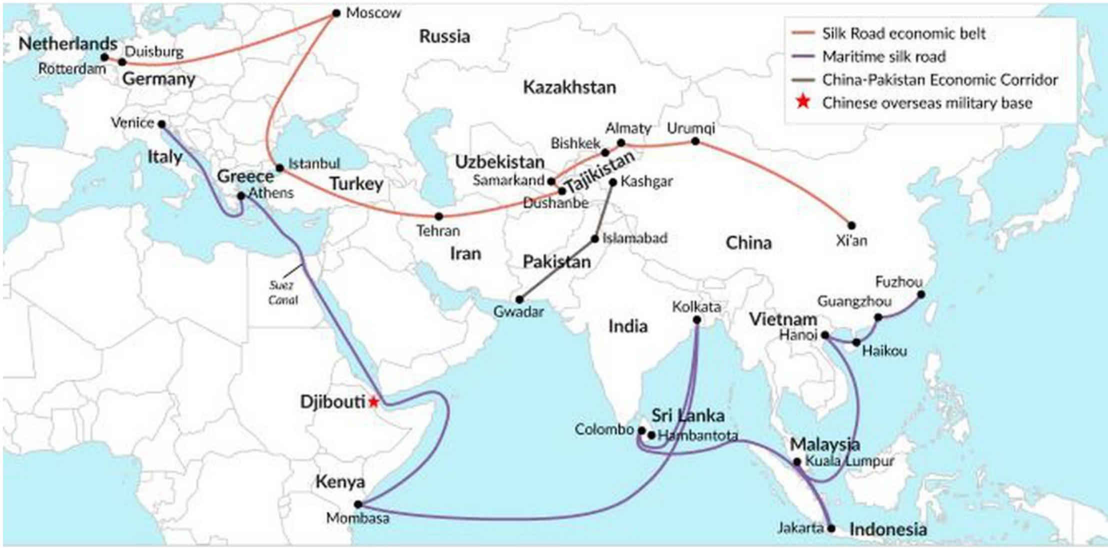
In 2013 China has first time officially announced “The Belt and Road Initiative”, to further strengthen cooperation and development with Russia and European countries, a path of business cooperation via many cities and Moscow is also included in. China's Belt and Road Initiative (BRI), is a clear manifestation of the rise of the Chinese economy and a wish to cooperate friendly with the neighbours. It is, at its heart, a massive world-wide infrastructure project, reaching back into the heart of Europe. China has initiated $US1 trillion in projects, including roads, railways, ports and maritime routes to facilitate the new and revived trade corridors. (Howard, K. W., & Wu, J. 2015). When complete, the plan will incorporate countries that combined account for 60 percent of the world's population and one-third of its GDP.

Followed this announcement was the creation of a lot of new financial institutions and economic cooperation projects in central Asia and Europe. Trade and investment are at the core of the China-Europe relationship, China’ s “The Belt and Road Initiative” adds a new dimension to the connection among Central-Asian and European economic entities. (Xinghua, 2013)

Since the announcement of China’s “The Belt and Road” initiative, 70 countries have already joined in this special activity. It encompasses the construction of a giant transportation system, including railways and highways, sea and air communications, power lines and pipelines. These projects have the potential to become an engine of economic development for many Russian cities (Mikhail Magid, 2018). So many economics are interested in how this new initiative is going to develop and why Russia needs to maintain its place along with it.

Figure 4: The China's Belt & Road Initiative

China's Belt & Road Initiative



This initiative has two unique characteristics:

1. Huge investments in transport infrastructure and logistics hubs.
2. New financial instruments and development banks to finance these investments.

2.2.2 The influence of "Belt and Road Initiative" to both countries

Globalization, which has long been discussed, is now an integral part of reality. Individual countries are becoming nodes in a single trade, financial, industrial, and informational system. A lot of modern products, whether industrial or agricultural, are being assembled more and more like LEGOs. (Bulis, A., & Skapars, R. 2014). For example, crops grown on Russian soil from foreign seeds are harvested using equipment purchased from the European Union by workers from former Soviet republics. In such conditions, the central challenge becomes one of communication and logistics, and whichever country can build optimal transportation routes to new markets receives an advantage. On October 30, an important part of the route opened; the Baku-Tbilisi-Kars transportation corridor (BTK) is at the heart of the emerging Eurasian market, which covers 65 percent of the population, 75 percent of energy resources and 40 percent of the planet's GDP. China in the east; Turkey and Europe in the west; Russia in the north; and Iran, the Middle East, and India in the south. (Wang, X., Zhang, J., & Sun, D. 2017).

In such conditions, the survival of the transportation industry is reliant on the creation of a denser, more user-friendly communication system that can deliver the desired goods as quickly as possible and as cheaply as possible to the right destinations. The transportation industry, however, is struggling to find its place in the sun, as the "Belt and Road Initiative" is expected to reduce the time of transporting goods from China to Europe from 30 days to 12-16. (Chen, Y., & Liu, Y. 2016).

For China

From the function of international business, we could figure out that the international logistics could bolster the poorer countries, which are located along the initiative Belt and Road, to the south of China, which are relatively richer and have a big supplier power to satisfy the demand of those countries. And this could also boost global trade. Domestic regions are expected to benefit too. Especially the less-developed border cities in the west of China. The economic benefits, both domestically and abroad, could continue sustainably by keeping China's national economy buoyant. (Anna Bruce-Lockhart, 2017)

Additionally, Chinese companies can gain through the construction of the domestic market set– such as those in transport and telecoms, by investing in this they can also become more competitive and grow into global brands. What should be mentioned in the Chinese manufacturing industry, mainly in the creation of steel and heavy equipment, could find huge demand along the initiative Belt and Road, this could also in return promote the level of Chinese manufacturing companies and the quality of their goods (Anna Bruce-Lockhart,2017).

For Russia

Since Russia is located between the Asia-Pacific region (APR) and Europe, more than $1 trillion could flow along a potential trade route, bringing an annual growth rate of 4-5 percent. (Andrey Movchan,2018) Assuming that Russia would be able to secure just half of the commodity flow between the APR and Europe after constructing an effective "northern silk road," and that the gross transit revenue will be 7 percent of circulation, then gross revenue from this business be a very considerable number.

At the same time, the transportation infrastructure will work for domestic needs, creating many jobs and attracting a significant number of foreign workers and visitors each year, which would ensure the growth and development of the regions along the road. Many foreign investors will translate their eyes to Russia and a huge amount of investments will pour into Russia. In principle, Russia could receive up to $50 billion a year from this industry.

2.2.3. The future of the initiative Belt and Road

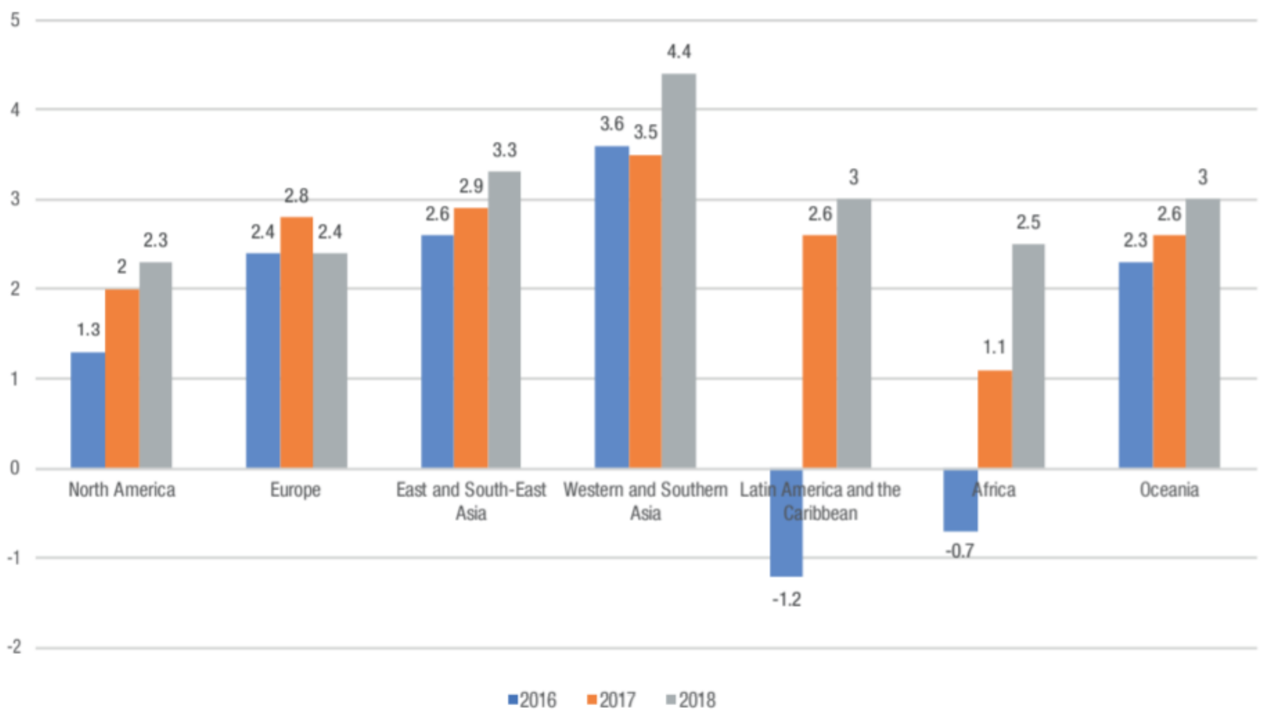
The International Monetary Fund (IMF) fully appreciates the importance of the "Belt and Road Initiative" for the global economy. Analysts believe that the scope of foreign investment from China alone in these infrastructure projects could reach $1 trillion over the next 10 years. So far, there are 70 countries included in the initiative, but this number could grow to 100 in the near future.

2.3. The contemporary situation of container terminals

2.3.1 The importance of container terminals in Sino-Russian trade

During this economic booming up, we could not ignore the contribution of international logistics, they are playing a unique role in the communication of Russia and China. Among those logistical infrastructures, seaport terminals are the basic elements of building ties between the two countries. The first internationally-standardized container terminal was introduced in the 1960s. Since that time, the world container trade volumes have rapidly expanded, and over 11 billion tons for now. The performance measurement and efficiency improvement of those container terminals have also become an essential component along the way of the "Belt and Road". Thanks to the development of economic globalization, worldwide trade has grown rapidly, and the container throughput, which can represent the international trade of different sides, is increasing continually. With the booming up of international trade, the volume of ports with container terminals grows up as well.

Figure 5: The volume of ports with container terminals growth 2016-2018 (percentage)



up from 2.1 percent in 2016. World container throughput stood at 752 million TEUs, reflecting an additional 42.3 million TEUs in 2017, an amount comparable to the port throughput of Shanghai, the world's busiest port.

Since 2003, China has been ranked as the first country in total container throughput of the world, a lot of important Chinese seaports have been known by the public. Most of the famous terminals of China are lying in the south of China such as Shanghai. And under the background of political assistant and economic globalization, the construction of efficient container terminals is becoming a top priority in economic development.

Figure 6: The largest ports in China, from chinaperformancegroup.com, 2018

In the process of international business, international logistics have become an important attributor to this global economic connection, and those international seaports consistently play a significant role in this process, the container terminals are responsible for the management process of 'planning, implementing, and controlling the physical and information flows concerned with materials and final goods at the point of origin'. As we believed, everything is hard to start, the container terminals who are taking care of the beginning of international business trade, have irreplaceable significance. In Sino-Russian trade, those terminals are paying attention to the beginning of the physical movement of products in the form of raw materials at their original point (Chen, Y., & Liu, Y. 2016). Every international trade starts from those international seaports, as well as the supply chain, and the transport line crosses the international border to service for the Sino-Russian trade.

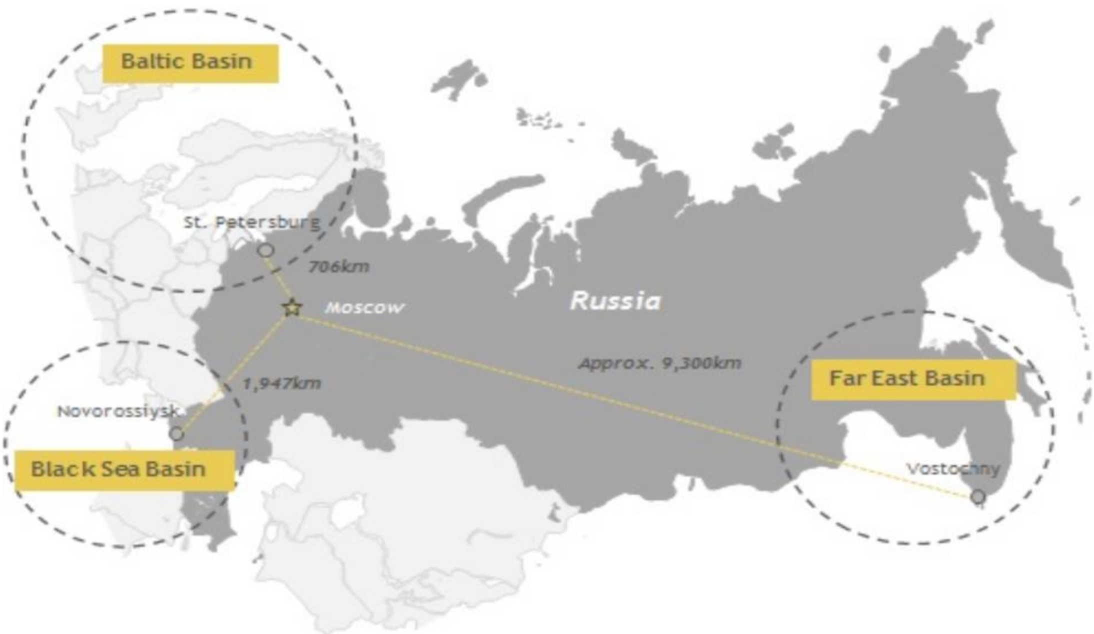
2.3.2 The development of container terminals in Sino-Russian trade

With the opportunities to cooperate between China and Russia growing day by day, demand for key international logistics services is heating, continuous performance improvement of international ports must follow as well. Chinese firms are searching and continue to build appropriate seaports to translate their products, while Russia can consolidate its position as a major transit country and become a full Eurasian bridge in Sino-European trade between the east and west. (Christoffersen, G., & Zuenko, I. 2018).

It should be mentioned that, as one of the very representative port cities in Russia, the Vladivostok contributes a lot to the cooperation between Russia and China. “the Russia Vladivostok trading port co., LTD”, which was built in 1897, One of the largest ports’ groups in Russia's far east, in 2016, it handled 5.12 million tons of freight, and almost 40% was coming from China. This free port of Vladivostok is a good brand. The city of Vladivostok is well known to many Chinese firms and it helps to promote the amount of business trade and the level of convenience.

In June 2017, it has signed a memorandum of understanding on cooperation with Tianjin port (group) co, from China. The two sides will accelerate the development of international shipping container business between the two ports and provide the impetus for the international business structure construction.

Figure 7: The Russian ports location, from worldoiltraders.com



Moreover, due to the gradual ice retreat and advances in icebreaker technology, it occurs to Russian that maritime lines across the Arctic Ocean are possible. Northern Sea Route (NSR) becomes attractive when considered exclusively from economic and geographical perspectives.

Global warming and extension of the navigation season, increase in traffic flow in the Arctic region as a whole, and shift of centers of economic activity in Asia in a northward direction, it is rational that Russia has a willingness to build and develop more huge-size ports along the Arctic Ocean coast.

Figure 8: The Northern Sea Route (NSR)

2.4. Research objectives

With the description of the research context, we have provided the evidence that container terminals management is gaining more and more attention, the container throughput handling capacity has become an important indicator of the industry. The performance measurement and promotion of container terminals are always being a hot topic for science research. Scientific research should be rigorous and objective, in different backgrounds the results will be different. And the conclusion of this study should have practical significance in the contemporary trade situation of Russia and China, based on the context of “The Belt and Road Initiative”.

2.4.1. Research gap

Based on the description above, we have a clear knowledge about the importance of container throughput handling performance management of container terminals to international cross-border trade. The efficiency of port operations has long been valued by port operators and managers. Scholars have begun to pay attention to the measurement of container port efficiency earlier and many scholars have done a lot of empirical research on container ports. However, there still exist some research gaps.

At first, a lack of empirical studies on the performance measurement and evaluation of those container terminals, which are serving in the Sino-Russian strategical context, the efficiency of container ports along the Chinese Maritime Silk Road has not received the attention of operators. Most of the samples selected in the literature before are concentrated in ports in a specific country or region, and the coverage is relatively limited. The number of studies on port operations under current unique policy conditions is insufficient. These previous researches all have different research backgrounds and pre-conditions, some were conducted in the context of the economic depression, aimed to find ways to stimulate economic recovery, and some were measuring the effectiveness of industrial reform.

It occurs to me that due to the particularity of the Sino-Russian relationship and special political assistance, the ports' operational performance may be influenced by some other factors, in this case, the research context is different. The terminals are operating in different external environments, different external conditions may have an impact on efficiency. Considering the geographical issues, as well as culture, political factors, economical background, in a different situation and under the different economical background, more or less, the investigation conclusion will have differences, not to mention the current booming-up Sino-Russian trade situation (the continually increasing demand can also influence the terminals' performance). However, most of the current studies have not considered the impact of the specific economic context of the Sino-Russian strategical relationship. And there are also certain defects that very little studies considered the special context of "the Belt and Road Initiative", there is still insufficient literature to study the influencing factors of port efficiency under the new strategic background.

Next, all of the studies focused only on the general operational performance, none of them considered the terminals' throughput handling performance, which is a more specific research objective. Most of those previous studies concentrated on only the overall efficiency measurement, the result they were searching is only the overall efficiency score of different ports. Further the previous researches do not figure out the question, what kind of factors that the terminal authorities truly need to concentrate on, there is no such research which identified the attributes of container terminals' throughput handling capacity.

To cope with the increasingly fierce competition and gain more space for development, many port authorities have increased the competitiveness through measures such as large-scale construction of berths, equipped with advanced mechanical facilities. However, good results are not always obtained, over-investment sometimes caused the idleness and waste of resources.

By analysing the throughput handling performance of the main container terminals, understanding the actual operation of the port can enable port companies to clearly understand the factors affecting their container throughput handling capacity and help them allocate resources reasonably, furthermore provide a basis for the government to formulate development plans and management countermeasures.

To sum up, the previous research conclusions may not apply to current Sino-Russian conditions. Thus, difficulty in the improvement of terminals' throughput handling capacity within the initiative "Belt and Road" exists. We don't know how they are working right now and which prospects they should focus on to achieve improvement. The reason for me to do this research is the inefficiency of throughput handling in the existing business situation and the wish to achieve performance improvement.

2.4.2. Research objectives and questions

A relative lack of research on the throughput handling performance measurement of these container terminals, leaving this an under-researched area. In this research, the focus will be on the container throughput handling capacity measurement of those container terminals. The research goal is to evaluate the potential to improve the sea port container terminals' throughput performance. The research objectives are to identify the influencing factors of container terminals' throughput performance and determine the best practices within Chinese-Russian container terminals industry, finally measure the technical efficiency of container terminals from chosen sample and provide suggestions for performance improvement.

To cover the above-mentioned research gaps and achieve research objectives, it is necessary to answer the following research questions:

1. What are the main factors influencing the container terminals' throughput handling capacity?
2. Compared with the best practice of the industry, how efficient are those chosen sample container terminals in container throughput handling?
3. What are the main steps to improve the container terminals' throughput handling capacity, in order to increase the output (container terminal's throughput) while keeping the level of inputs?

For the first question, as we explained in the theory background, the given research uses the operational efficiency to indicate terminals' container throughput handling performance. Regarding the efficiency measurement of container terminals, it could be measured by productional input-output ratio.

In any container terminal, there are too many kinds of inputs that should be consumed every day to ensure daily operation, some are not important but some are playing a significant role and should be paid more attention because they have a huge influence on the performance but what are those main components?

For the second question, the given research has used the frontier analysis methodology to conduct quantitative research, the great point is that this method will show us the best practice of operational performance in this industry, based on the current level of technology. This best efficiency is the so-called “frontier”.

The research has selected data of those container terminals as research samples, who were reported as the most “successful” or “representative” individuals in the maritime transport industry. Logically speaking, at this stage their efficiency should be the highest and most representative, their production arrangements should be the most reasonable as well.

But what will happen if we will use the frontier analysis to get the most efficient possibility? How efficient they are and how much is the inefficiency? The given research will provide a visualization of compare results as well.

For the last question, as we explained before, improving the efficiency means given the technology, find the way to produce a larger output from the same inputs, or the same outputs with less of one or more inputs without increasing the volume of other inputs. Comparing with the industry best practice, the given research can indicate the space for improvement and provide suggestions for improving through benchmark approaches.

The performance benchmarking can help container terminals to find their status in the Sino-Russian trade because performance measurement might be referred to as performance monitoring or performance auditing. Assessing the relative level of performance in key areas or activities in comparison with others in the same sector. With the result of strategical benchmarking, they can also know which factors may influence their performance and thus pay attention to those sectors to get a promotion.

2.5. Summary of chapter 2

In this chapter, we have made a clear description of the Sino-Russian trade contemporary situation. Based on the before-mentioned facts, the volume of international commercial trade will continually increase soon. As a consequence of the proposal of “The Belt and Road Initiative” communication policy, the Sino-Russian international trade will be more and more frequent.

During this process, we cannot ignore the significant contribution that comes from maritime trade, which occupied almost 90% of the total international trade volume. Considering foreseeable prosperity in international trade and gradually fiercer competition among those ports industries, the ports’ throughput handling capacity measurement and promotion are becoming a more and more important issue for those companies and have become a critical task for the sustainable development of international business

There are lots of different international seaports classified by cargo types, in this research, we would focus only on the seaports with container terminals because of the unity of measurement unit (TEU) and the ease of measurement. Furthermore, considering the argument of Wang, Song, and Culliane (2002) that container terminals are more suitable for one-to-one comparison than whole seaports, physically the single seaport can consist of one or more different terminals. Therefore, the relevant objectives comparison of ports and terminals cannot be conducted due to different operating agents at the ports. With this in mind, we will consider and compare only container terminals in the given research (here from, the container terminal and seaport are used interchangeably) (Liu. 2010).

Based also on the literature review concerning the researched subject, the research gap was identified. Managers must pay more attention to the empirical studies of the performance measurement and evaluation of the container terminals. However, there exists a relative gap of research on the performance measurement of those container terminals, leaving this an under-researched area.

With the research gap left to fulfil, the given research aims to benchmark the operation performance of container terminals of Sino-Russian trade under the background of "The Belt and Road Initiative", using the mixed methodology, consisting of questionnaires, interviews and advanced quantitative research methods to benchmark, identify and evaluate the best practices, further to find out the space for improvement and provide the suggestions to achieve this target.

Chapter 3. The methodology of the study

This chapter investigates the methodology of the industry performance measurement study, which included not only qualitative but also quantitative methods. The core methodology of the given study will be quantitative ways, mathematical models of various approaches for efficiency measurement, which are used in this research to achieve research objectives. According to the literature review, we suggest that Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) are useful methods that have been applied in previous studies for container terminals' throughput handling performance assessment. But at first, this study will start with a qualitative methodology, to indicate the potential effective attributes (inputs) and representative indicators (outputs), basing on the results of interviews and questionnaires with experts and experienced related persons. Furthermore, the decision of which inputs and outputs will be chosen in a further quantitative study will be made.

3.1. The first stage of the research

In the first stage, we will research questionnaires and interviews, to communicate with industry experts and authorities, top/middle manager of terminals' operating companies, get access to primary industry practical experience and professional knowledge. And the results of this stage can be seen as the stimulation of further research.

When the researcher conducts the questionnaires and interviews survey, he can understand the essence of the contemporary phenomenon using multiple sources of evidence (Yin, 2003). While understanding and interpreting the real phenomenon, we are going to explore a lot of relevant events. Among various sources of evidence, we can divide them into two groups: one is human-centred, such as interviews, while the other one is document-centred. The truth will be clear and understandable when it is told by someone who has deep knowledge in this area. The interview is one of the typical methods of case analysis. If we prepared a real meaningful questionnaire, we can receive lots of useful information that can be identical to our research. Of course, not every individual can be a good choice for a research interview, the researchers have to choose the interview targets very carefully.

The fact is sometimes it is not that easy to conduct a great interview, series factors should be considered before all of the further activities, such as the accessibility of interview targets, the attitude of them, the possibility of information disclosure and et. Facing such problems, the researchers can use other methods as a substitution. The document analysis could be another optimal choice for them. The company's official website, the company's recent policy, and annual reports can be ideal resources of evidence, through which the researchers can discover the truth.

During the investigation process of container terminals' throughput handling performance measurement, the most significant part can begin with finding the truly effective attributes, which can influent the performance of container terminals and should be paid lots of attention during the process of investigation, the research data of further quantity methodology should also be collected under this precondition. Besides, the decision about choosing the representative indicators, which can specifically express the efficiency of objectives, is also important. Both of these problems can be solved and the credibility of the research be ensured if we will conduct the first research stage successfully. Based on the opinions of industry experts and official documents, which kind of data we should collect can be eventually decided. Furthermore, the researchers can expand the study into a quantitative area. The first stage of the given research would be seen as a persuasive prerequisite work, and those theoretical propositions can be the basement for further mathematical research.

3.2. The second stage of the research: Stochastic Frontier Analysis

Same as a mathematical function model building method, but different from traditional regression analysis, the SFA method not only admits the existence of technical inefficiency but also acknowledges the fact that random shocks outside the control of organizations can influence the final output as well. The stochastic frontier analysis is a more objective mathematical efficiency measurement model: the impact on the output of shocks due to random variation of any situation which is beyond the organization's control is distinguished from the influence of variation of company's technical inefficiency. In more detail, the error term in the SFA method is composed of two parts. The first one-sided (only negative) component accounts for the effects of technical inefficiency relative to the stochastic frontier, while the second symmetric component allows random variation of the frontier across firms, capturing the influence of measurement error, other statistical noise, and random shocks beyond the limits of organization's control (Wang, 2004).

The original specification of the model can be expressed in the following form,

$$\mathrm{Y}_i = \mathrm{X}_i \beta_i + (\mathrm{V}_i - \mathrm{U}_i),\ i = 1, .., n,$$

Where Y_i is a production of the i-th firm;

X_i is a vector of input variables;

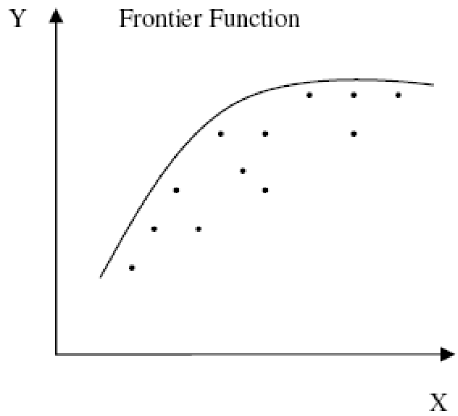
β is a vector of unknown parameters to be calculated;

V_i is a symmetric disturbance term that accounts for the random variation of the production function across economic units;

U_i is a one-sided disturbance term responsible for technical inefficiency (hence, technical efficiency will be 1-U_i).

The disturbance term due to technical inefficiency must be non-negative ($U_i \geq 0$), which reflects the fact that actual output lies on or below the stochastic production frontier, and the production frontier of a single input and single output can be shown as below:

Figure 9: The stochastic production frontier



The first step of the SFA benchmarking method in evaluating the efficiency of firms is to specify a mathematical functional form. Then the distribution assumptions for the residual (U_i) and random noise (V_i) should be specified.

The part job of choosing a functional form for the stochastic frontier is of crucial importance because the form of the mathematical function establishes the relation between the **single output** and explanatory variables, and different functional forms may have differences in the compatibility of the model and real statistic, a better functional form can be more in line with real statistics. The table below lists the most commonly used functional forms in stochastic production frontier studies (Liu 2010).

Table 2: Functional forms applied in SFA studies

Linear	$y = \beta_0 + \sum_{n=1}^{N} \beta_n x_n$
Cobb-Douglas	$y = \mathrm{e}^{\beta_0} \prod_{\mathrm{n=1}}^{\mathrm{N}} x_n{}^{\beta_n}$ or $\ln y = \beta_0 + \sum_{n=1}^{N} \beta_n \ln x_n$
CES	$y = \beta_0 (\sum_{n=1}^{N} \beta_n x_n{}^{-p})^{-\gamma/p}$
Quadratic	$y = \beta_0 + \sum_{n=1}^{N} \beta_n x_n + \frac{1}{2} \sum_{n=1}^{N} \sum_{n=1}^{M} \beta_{nm} x_n x_m$
Translog	$\ln y = \beta_0 + \sum_{n=1}^{N} \beta_n \ln x_n + \frac{1}{2} \sum_{n=1}^{N} \sum_{n=1}^{M} \beta_{nm} \ln x_n \ln x_m$

The linear function is the most basic functional form, which assumes that there is a linear relationship between single output and inputs. This assumption is out of reality and the functional form is not able to describe complex systems. Therefore, researchers come up with new complex functional forms such as the Cobb-Douglas and Translog functional forms that can better explain the phenomenon.

Introduced by Cobb and Douglas (1928), the Cobb-Douglas form has an exponential relationship, which takes the form of linear function after logarithmic transformation. And Christensen, Jorgenson, and Lau (1971, 1973, 1975) presented the Translog functional form, which represents a quadratic function with logged arguments. These function forms considered the existence of non-linear relationships between the different variables.

After the choice of functional mathematical form, the next step is to specify the distribution assumptions for the statistical noise (V_i) and the inefficiency component (U_i) which are distributed independently of each other and the regression. The normal distribution is commonly used for specification of V_i distribution assumption, because the value of it can be positive or negative. Meantime the distribution function of U_i, which should be non-negative only, can be Half Normal, Exponential, Truncated Normal, and Gamma distribution. To separate the technical inefficiency U_i from statistical noise V_i, the strong distributional assumptions on each component should be made by a careful observation of the data. With the different assumptions, the mathematical functional model we will get will be different as well.

Meanwhile one of the potential drawbacks of the model is the assumption that input variables and technical inefficiency terms are independent, which is rather unrealistic because technical inefficiency is likely to be correlated with input variables selected by the firm. The model is too simple that it only considers the relationship between efficiency and other influencing factors, and the stochastic frontier analysis method is influenced by subjective issues, for instance, selecting influencing factors. At the same time, the parametric method needs to determine the function form manually, and subjective intervention by researchers is inevitable. This issue cannot be ignored and can be seen as a limitation of the stochastic frontier analysis.

When all those assumptions are set, using software package STATA, the researchers can build the mathematical model and find the full efficiency production frontier, which will be shown in a mathematical functional form. The estimation of parameters is conducted by the ordinary least squares (OLS) method. Through this model, we can still figure out which kind of attributes have more influence on the companies' performance, based on the specific parameters indicated in the mathematical form. Furthermore, the different researching objectives can be compared with the fully effective production function and evaluate the efficiency of their own.

3.3. The third stage of the research: Data Envelopment Analysis

The parametric method needs to artificially determine the function form, the selection of the probability density distribution of the technical error term Ui, and other issues. If it is not handled properly, it will affect the rationality of the model results. The shortcomings of human subjective intervention in the SFA model are unavoidable, and its implementation process is susceptible to human subjective factors.

To overcome the limitation of the parametric function model, the improved DEA method can be used to study port efficiency. The DEA model is defined as a non-parametric method of measuring the efficiency of decision-making units (DMUs) that perform the same tasks in a production system using similar multiple inputs to produce similar multiple outputs in different quantities. Its main feature is that the method doesn't require building a parametric model with explicitly specified mathematical form based on the data collected and it does not need to subjectively assign relative weights to each indicator. It is operated by constructing a relative efficiency score as the ration of a single virtual output to a single virtual input without pre-defining a production function (Thanassoulis, 2001). The model has strong objectivity. Also, DEA can handle large numbers of any variables and constraints, and this relaxes the requirements, which are often encountered when the choice of inputs and outputs is limited because the techniques utilized will otherwise encounter difficulties (Cooper, 2006). Moreover, this method can reveal the sources of inefficiency basing on the operating result, those operating results can be analysed and quantified for every evaluated decision-making unit, to help them find the shortage and achieve improvement.

However, the DEA model still has two problems: one is that this method doesn't give a specific explanation about statistic noise, which brings too much pressure to the data analyst, and how to guarantee the accuracy of statistical results. As the result of DEA operation can be just a benchmark score, this makes the result too sensitive to the changes of inputs and outputs, even the collection of those data can lead to different scores. And the other is that when the decision-making units under investigation are efficient, the efficiency between decision-making units cannot be distinguished, which will be affected by external environmental factors and random errors, which will lead to the untrue of port efficiency evaluation.

Among all the models in the context of DEA, DEA input-oriented model and DEA output-oriented model are the two widely-used models. The core conception of DEA input-oriented model is to minimize inputs while keeping the given outputs level, and the DEA output-oriented model means to maximize the outputs without changing input size. In this research, we will highlight the use of the output-oriented model, since it is logical and easier for container terminals to focus on output data, due to the inflexibility of inputs for the container industry and intuition of output data. Meanwhile, the efficiency value obtained from the DEA-CCR model is the comprehensive technical efficiency, which includes scale efficiency, not pure technical efficiency. The BBC model is based on it and separates pure technical efficiency, excluded the effect of scale efficiency. The relationship between the three is, scale efficiency = comprehensive technical efficiency / pure technical efficiency

CCR model

Introduced by Charnes, Cooper, and Rhodes (1978), the DEA-CCR model assumes constant returns to scale. Returns to scale reflect the degree of change outputs with the change of inputs, if the outputs increase or decrease in the same degree with the change of inputs, this means the company's production exists constant returns to scale. In this case, it is assumed that the scale of operation of a DMU does not affect its productivity, constant productivity exists, thus all observed production combinations can be scaled up or down proportionately. Focus on the core task, minimalize the inputs while keeping the give output level, the DEA-CCR model is input-oriented.

Normally, suppose there are m input variables and s output variables. Let the inputs for DMU_j be $x_j = (x_{1j}, x_{2j}, \dots, x_{mj})$ which produce the outputs $y_j = (y_{1j}, y_{2j}, \dots, y_{sj})$. Then the vectors X_j and Y_j accordingly, form the J^{th} rows of the input data matrix X and output data matrix Y as follows:

$$\mathrm{X} = \begin{pmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{pmatrix} \; , \quad \mathrm{Y} = \begin{pmatrix} y_{11} & \cdots & y_{1n} \\ \vdots & \ddots & \vdots \\ y_{s1} & \cdots & y_{sn} \end{pmatrix}.$$

If we assume the weights for input and output to be defined as V_i and U_i, respectively. Then, virtual input and virtual output are formed for each DMU:

Virtual Input = $(v_i x_{10} + \cdots + v_m x_{m0})$

Virtual Output = $(u_i y_{10} + \cdots + u_s u_{s0})$

Using linear programming, the core task of the model seeking to determine weights with maximization of the ratio:

$$\frac{\text{Virtual Output}}{\text{Virtual Input}}$$

With the given input and output data, the efficiency of each DMU is computed once, and after that n steps of optimization (one for each DMU_j) are made to be completely estimated. We can change the formulation above and the values of input weights v_i and output weights u_i for each DMU are obtained by fractional programming.

$$\max_{\mathrm{v},u} \theta = \frac{u_i y_{10} + \cdots + u_s y_{s0}}{v_i x_{10} + \cdots + v_m x_{m0}},$$

subject to $\frac{u_i y_{1j} + \cdots + u_s y_{sj}}{v_i x_{1j} + \cdots + v_m x_{mj}} \leq 1 \; (j = 1, \dots, n)$

$v_1, v_2, \dots, v_m \geq 0, \qquad$ and $\quad u_1, u_2, \dots, u_s \geq 0.$

The constraints mean that the efficiency ratio θ should not exceed 1 for every DMU. The objective is to find weights v_i and u_i, which maximizes the ratio of θ. As a result of the constraints, the optimal objective value θ is at most 1.

To simplify the problem, the above fractional programming is replaced by the linear programming that, according to Charnes, Cooper, and Rhodes (1978), the efficiency program equivalent to fractional form:

$$\max_{\mu,\gamma} \theta = \mu_i y_{10} + \cdots + \mu_s y_{s0},$$

subject to $\gamma_i x_{10} + \cdots + \gamma_m x_{m0} = 1$,

$\mu_i y_{1j} + \cdots + \mu_s y_{sj} \leq \gamma_i x_{1j} + \cdots + \gamma_m x_{mj}$ ($j = 1\ldots, n$),

$\gamma_1, \gamma_2, \ldots, \gamma_s \geq 0$ and $\mu_1, \mu_2, \ldots, \mu_m \geq 0$.

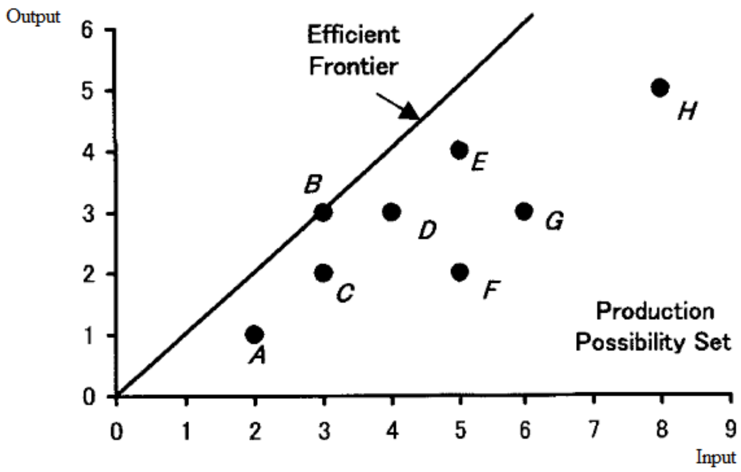
Therefore, the optimal solution with values θ*, v* and u* can be found by solving this linear programming problem, where v* and u* are values with constraints.

Charnes, Cooper, and Rhodes (1978) define CCR-efficient DMU_0 as a unit with θ*=1 and at least one optimal pair of values (μ*, v*), where μ*>0 and v*>0. Otherwise, DMU_0 is considered CCR-inefficient.

The production possibility set P consists of a set of feasible activities of (x, y), where x refers to the input value, and y is the output, which is defined as the following:

$$\mathrm{P} = \left((x, y) | x \geq \mathrm{X}\lambda, y \leq \mathrm{Y}\lambda, \lambda \geq 0\right)$$

As an example, the production possibility set of 8 DMUs are presented in the figure 10:



In this case, there is only one CCR-efficient unit, DMU_B , which is located on the efficient frontier (formed by efficient DMUs). Other DMUs are inefficient. The production possibility set envelops all the data points within the region enclosed by the frontier line, the vertical line through H, and the horizontal line passing through A.

According to Cooper (2006), for each inefficient DMU from production possibility set, its reference set or a peer group E_0 is composed of CCR-efficient DMUs and defined based on the max-slack solution by:

$\mathrm{E}_0 = \{j|\lambda_0^* > 0\} \quad (j \in \{1, \dots, n\})$.

Based on this form, we can figure out the production efficiency of each DMU, investigating the ratio of inputs changing to outputs. Improvements can be identified by referring to inefficient behaviors to the efficient frontier.

BCC model

Introduced by Banker, Charnes, and Cooper (1984) in comparison to the DEA-CCR model, the alternative DEA-BCC model allows **for variable returns to scale**, i.e. increasing, constant, and decreasing returns to scale. It is more realistic and also important to consider the scale size since it does impact productivity when a change in input levels results in a non-proportionate change in output levels.

Being an extension of the CCR model, BCC model estimates the efficiency of DMU_0 by solving a similar linear problem by adding the convexity constraint for γ.

$\max_{\theta_B, \lambda} \theta_B,$

subject to $\theta_B y_0 - Y\lambda \le 0$

$X\lambda \le x_0,$

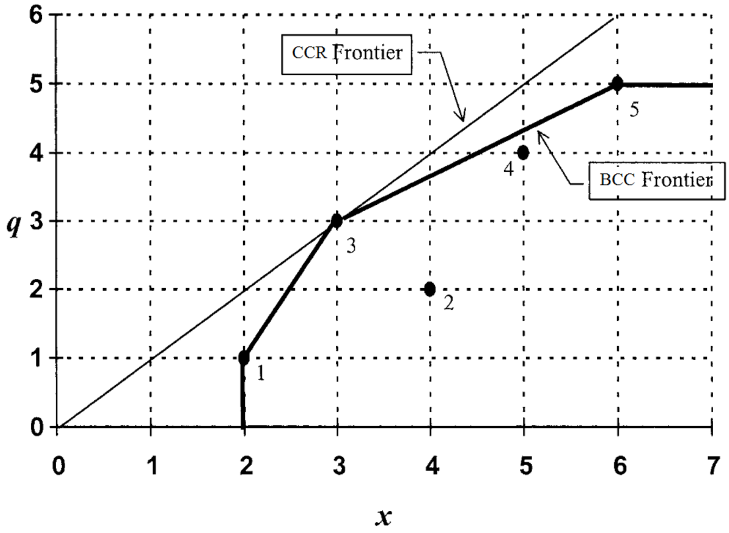
$\lambda \ge 0$ and $e\lambda = 1,$

Therefore, the optimal solution with values θ*, v* and u* can be found by solving this linear programming problem by the simplex method, where v* and u* are values with constraints.

According to Banker, Charnes, and Cooper (1984), DMU_0 is called BCC-efficient, if an optimal solution ($\theta_B^*, \lambda *, s^{-*}, s^{+*}$) satisfies θ_B^*= 1 and has no slack (s^{-*} = 0, s^{+*} = 0), where s^{-*} and s^{+*}refer to the maximum input excesses and output shortfalls. Otherwise, it is BCC-inefficient unit

The optimal objective value of the BCC model θ_B^* is not less than that of the CCR model, because the BCC feasible region is a subset of feasible region for the CCR model due to additional constraint. The future below demonstrates the difference between CCR and BCC models on the example of 5 DMUs, each with one input and one output:

Figure 11: CCR and BCC efficient frontiers (Coelli 2005)



In this example, DMU_3 is CCR- and BCC-efficient, while DMU_1 and DMU_5 are only BCC-efficient. DMU_2 is inefficient in both models, whose reference set consists of DMU_3.

According to Cooper (2006), the technical efficiency of the CCR model is called (global) technical efficiency (TE), since it doesn't take into account scale effect. In contrast, the BCC model expresses (local) pure technical efficiency (PTE) with the assumption of variable returns to scale. The technical efficiency scores estimated by the CCR and BCC models are commonly used to obtain a measure of scale efficiency as shown below:

$$\mathrm{SE} = \frac{\theta_{\mathrm{CCR}}}{\theta_{\mathrm{BCC}}}$$

The value of scale efficiency is not greater than one. SE = 1 indicates scale efficiency, while SE < 1 represents scale inefficiency. Scale inefficiency is due to either increasing or decreasing returns to scale which can be found by inspecting the sum of weights, $\sum \lambda_i$, under the specification of the CCR model. When this sum is equal to one, the DMU demonstrates constant returns to scale, while increasing returns to scale and decreasing returns to scale prevail if the sum is less than one or greater than one, respectively (Cullinane, Song, and Wang 2006).

3.4. Summary of chapter 3

This chapter has described the alternative approaches appropriate for efficiency measurement, the structure of given research is starting with a qualitative method and further expanded into a quantitative method. In the description of the quantitative methodology, the core job is to distinguish between the parametric and non-parametric methods. Within the context of parametric approaches, SFA was investigated, whereas DEA is the representative of non-parametric methods.

The given research started with typical qualitative research methods to identify the potential influential attributes and representative indicators. Depend on the information we could get from questionnaires, interviews and official documents, we can collect useful data purposefully. After that we conduct quantitative research method SFA and DEA, evaluating efficiency by defining frontier production function. SFA model provides measures considering not only random statistic error but also technical inefficiency, while the non-parametric DEA model is used for technical efficiencies assessment with variable returns to scale or constant returns to scale.

Through comparative study we can conduct the efficiency evaluation, using the parametric and non-parametric approaches to measure efficiency scores. However, there exists a lack of empirical study concerning their comparative effectiveness in the application, particularly in the container terminals industry. A comprehensive comparative study of these approaches can provide a profound, empirically justified methodology to efficiency measurement.

We cannot ignore that the given research does have a methodological problem. The main drawback of the parametric method (SFA) is that this method is too simple because it only considers the relationship between output and other influencing factors. It does not take into account other more complex meanwhile difficult to discover influencing factors. The relationship between these factors is not taken into account. The SFA method is influenced by human subjective factors when selecting influencing factors. These factors are decided after the conclusion of the case analysis. Based on the recommendation of industry experts, I have chosen the most influencing production inputs and most representative outputs, furthermore, the data was collected and the research models were built. Generally speaking, it is hard to avoid the shortboard of subjective intervention.

Even though these two basic methods commonly used for studying frontier production functions, both of which are used in port performance evaluation, of which the DEA model is most commonly used in port performance evaluation. It should be pointed out that the performance measured by SFA and DEA models is relative, the results of the study should be relative too. Its efficiency values are highly comparable within the research samples, but between different samples are not comparable.

Chapter 4. The empirical study of container terminals

This chapter presents the empirical part of the throughput capacity efficiency research, consisting of three stages, mix-using of qualitative and quantitative methodology. Within the second and third stage of research, the parametric and non-parametric methods are used together to complement each other. And comparative analysis of computed efficiency scores was conducted, trying to explain the reasons for inefficiencies.

At the first stage, through communication with industry experts in the way of questionnaires and interviews, the most influential inputs and the most representative output of terminal throughput handling capacity are selected from series of factors based on authorities' extensive experience and knowledge. Following we introduced the selected factors in detail and described the data, which was collected according to these selected factors.

In the second stage, we applied parametric analysis for the objects of the sample. Firstly, we used the average production analysis and Principle Components Analysis to test each variable we selected from the first research stage. Next, the Stochastic Frontier Analysis was used to build the parametric function and estimate technical efficiency. The calculation was made through the statistical software package, Stata 12.0.

In the final research stage, we calculated efficiency scores for the DEA approach by using DEA-Solver 3.0, where two different DEA specifications, DEA-CCR and DEA-BCC models were conducted for outputs-original evaluation.

4.1. The first stage of the research

Based on the previous literature review, there are a large number of factors concerning the terminals' throughput handling capacity. In order to select the most influential inputs and representative outputs from them, we decided to conduct our research from the questionnaire survey. As the most efficient and direct research method to obtain professional knowledge and practical experience, the questionnaire can help researchers avoid useless work and achieve research objectives.

Almost all the registered ports within Sino-Russian maritime transportation are listed on the internet, but not every one of them has publicized the contact information of the ports' operating company. We have gone through all of the ports, who have open contact information of local operating companies and have container business serving Sino-Russian trade at the same time. According to the ranking results of the 2019 Statistical Annual Report of Russia and China, we have chosen the TOP ranked container terminals, who were reported as the most "successful" or "representative" individuals in the Russian and Chinese maritime transport industry. Logically speaking, at this stage their efficiency should be the highest and most representative, their production arrangements should be the most reasonable as well, thus we have chosen them as our research objects. And then the contact information of these companies' managers was collected, we sent them the questionnaires via email. We have chosen many companies respectively and equally from Chinese and Russian ports, making sure at least 100 contacts from each country could be collected and 100 questionnaires could be sent to each side.

The content of the questionnaire is mainly focusing on the questions, concerning the importance of various inputs and representative degree of different outputs. The results of the questionnaire turned out quite well, 200 questionnaires were sent out and 69 replies valid, including 24 answers from Russian companies and 45 from Chinese companies.

While the survey results of the questionnaire are enough for further research work, we decided to strive for further face to face interviews still, in order to avoid the "anchoring trap". The anchoring is known as a common and often pernicious mental phenomenon, which can establish the terms on which a decision will be made. When considering an answer, the mind gives disproportionate weight to the first information it receives. Initial impressions, estimates, or data anchor subsequent thoughts and judgments.

The answers provided in the questionnaire are limited to the knowledge level of the investigator, and it would also limit the respondent's thinking and trap them with "low-level answer". Thus, we asked questions about willingness to accept further interviews in the last page of the questionnaire, and received nine affirmative answers from middle managers of Chinese companies. Their answers in the interview gave us many innovative ideas for our research and also provided many suggestions for improvement.

Apart from the questionnaire and interview survey, we have also searched relative information of the chosen companies' official sites and annual reports as a supplement. Based on the information such as the investment budget of different projects, we could know what aspects of construction are priorities for terminal managers. As some of them are listed company, the input-output data disclosed in the annual reports and official sites do have certain reference significance for the given research.

According to the survey results of the first stage, we have decided on the choice of inputs and output. We introduced these factors in the above text and following collected data about them. The inputs we used the parameters of terminal labour, infrastructure, and equipment, which are the number of dockers, berth length, berth depth, the storage area, and the number of quay cranes. The total annual container throughput in TEU represents the container terminals' output. The table below shows the variables that were chosen for the analysis.

Table 3: Variables selected for measuring throughput handling capacity in the first stage

	Variable	Description	Unit
Input	L	The number of dockers	number
	SA	The storage area	hectares
	Cr	The number of quay cranes	number
	BL	The berth length	meter
	BD	The berth depth	meter
Output	Y	Annual container throughput	1000 TEU

4.2. Variables definition and Data description

4.2.1. Variables definition

The throughput capacity of the container terminal is evaluated by analyzing various indicators, which are normally separated into outputs and inputs. Based on the survey results of the first research stage, the choice of these factors has been made.

As a measure of the output of terminal production, annual container throughput is the most appropriate and widely accepted indicator of terminal output. Indicated in the literature review above, the majority of the previous studies incorporated it as an output measure, because it closely relates to the need for any inputs, such as cargo-related facilities and services, and is the foremost factor upon which container terminals are compared (Wang, 2004). Since the basic unit of output measurement is singer container and, irrespective of its size and its weight, the facility inputs for the movement of any container are more or less the same, thus, international measurement standards exist and we adopt Twenty-foot equivalent unit (TEU) per annum as the output measure.

Regarding the inputs of terminal activities, they come in many types and vary in importance. In our research, based on the opinions of industry experts, the chosen factors are the necessary facilities for container terminal production, namely, labour (the terminal dockers), land (berth length and depth, storage area), and equipment (quay cranes). As Dowd and Leschine (1990) argued, the productivity of a container terminal depends on the efficient use of land, equipment, and labour. Terminal productivity measurement, therefore, is a means of measuring the efficiency with which these three resources are utilized.

When considering the inputs of production activity, the number of labour logically should become the main factor for port performance evaluation. There are two methods to collect data on labour. The first one is to include the manpower into the model indirectly. This was pointed out by Notteboom, Coeck and van den Broech (2000) that labour information can be determined as a function of the port facilities due to a fairly stable and close relationship that exists between the number of gantry cranes and the number of dockers in a container terminal. However, due to the modern sophisticated technology and equipment, container terminals are applying more and more automatic systems (e.g. automated guided vehicles, automatic stacking cranes, etc.). Thus, there is not such a quantitative relationship between terminal facilities and the absolute number of the dockers. This indirect approach is not appropriate to collect labour data.

The second approach to incorporate labour as an input is to directly count the number of employees that work in the terminals (Tongzon 2001, Culliane and Song 2003). The limitation of this approach is the difficulty of obtaining the complete data and the potential measurement error due to the inaccuracy of information. Comparing these two methods I believe the inaccuracy and incomplete of the second approach can be eliminated through confirming with companies' official information and the data collected could contribute to the given research to some level, while the uncertainty of the first method is hard to accept or eliminate.

Apart from the labour factor, the terminals' land inputs used for port activities should be considered as well. Based on the results of the questionnaire survey, the first facility to be included in the model as a production input is the container berth using for operating. Two different metrics concerning berth can be incorporated: the total berth length and the number of berths. However, during the time of data collection I have found that the number of berths could be changed easily and subjectively, which brought to us the problem of data authenticity. Whereas the total berth length couldn't be changed that easy and the credibility of data resources can be guaranteed. It might be fair enough to consider the total length of berths in the given research to ensure the objectivity of research work

Besides, the berth depth is an influential factor that has been mentioned in the first research stage as well, as it determines the vessel type which can moor at the terminal. However, when all the data about berth depth was collected, we have found that the variance in this kind of data is relatively small compared with the variance of other kinds of inputs, almost the berth depth data of all container terminals are located between 15-17 meters, whose variance could be almost negligible. Thus, we have good reason to believe that the impact of this factor on container terminals' performance can be ignored, and the berth depth factor will not be included in further research.

Another important factor in the land sector that should be considered is the area for container storage. The containers are then transferred to the yard area, which is a storage facility. Thus, the total area of storage is categorized as essential inputs of terminal production as well.

Regarding the factors that represent the equipment using for terminals' activities, the given research has chosen the number of quay cranes as the priority of equipment to be considered in terminal efficiency evaluation. The quay transformation operation for loading and unloading of containers is the key operation in a terminal, which primarily drives the port productivity. What should be mentioned is that this may be problematic and may introduce bias into the estimates of production efficiency because the quay cranes are not the only type of equipment that contributes to terminal performance. Other equipment such as straddle carriers, mobile cranes, front-end handlers, reach stackers, top lifters, and forklifts are also used in many container terminals. One solution is to count the aggregation of all equipment. But it raises the question of comparability and equitability due to different capacities of different types of equipment. The other solution adopted in our research is to utilize the most important equipment for sea-land container handling, quayside gantry cranes. During the process of data collection, some mobile cranes are found to have large capacities (over 100 tones). In such cases, mobile cranes are also categorized as a quayside crane because they are capable of producing the same operations.

After determining to eliminate the variable of berth depth, the variables to be included in our model are shown in the table below:

Table 4: Variables selected for measuring throughput handling capacity

	Variable	**Description**	**Unit**
Input	L	The number of dockers	number
	SA	The storage area	hectares
	Cr	The number of quay cranes	number
	BL	The berth length	meter
Output	Y	Annual container throughput	1000 TEU

4.2.2. Data description

The sample we have collected consists of 58 terminals from the Russian and Chinese seaports in 2018. Among them, 13 terminals are from Russia. The other 45 container terminals are located in the south of China, both kinds of these terminals are involved in the Sino-Russian cross-border maritime routes. The reasons for including terminals only from Chinese and Russian ports are to highlight the Russia-China international trade research context. In this case, the typical terminals from other seaports or a global standard which include more observations may have no sense for the benchmarking of Sino-Russian serving terminals' efficiency.

The sources of the data were secondary, and most of the data was taken from the Chinese Containerization Statistical Yearbook 2019 published by China Statistics Bureau. Sometimes missing information was also collected directly from the official websites of the respective terminals when available. All Chinese and Russian terminals registered are listed on the internet. However, data sources including the required data, especially annual container throughput and terminals' detailed information could be missed. Thus, we disregarded terminals with incomplete information and let the remaining 58 container terminals be included in the sample set.

Table 5: Descriptive statistics of inputs and output variables of the chosen sample

Measure	Variables				
	Number of dockers	**The storage area**	**The number of cranes**	**Berth length**	**Throughput 2018, 1000TEU**
Average	219.0517	67.161	15.052	1220.481	2582.408
Standard deviation	18.042	8.676	1.371	156.089	381.9966
Skewness	2.780	12.985	0.356	11.923	2.771
Range	619	414	42	7251	13090.9
Minimum	100	3	3	131	69.1
Maximum	719	417	45	7382	13160
Total sample	12705	3895.34	873	72008.39	149779.7

4.3. Stochastic Frontier Analysis

4.3.1. Regression analysis

Before conducting the Stochastic Frontier Analysis, we decided to use regression analysis to check, whether all the collected original data are suitable for further research and whether all the factors selected in the first stage of the study should be included in the further model building.

For the parametric function, we assumed the appropriateness of the log-linear Cobb-Douglas model. The model has the following functional form:

$$\ln Y_k = \beta_0 + \beta_1 \ln L_k + \beta_2 \ln SA_k + \beta_3 \ln Cr_k + \beta_4 \ln BL_k + e_k$$

where Y_k specifies the dependent output variable of the kth container terminal, k = 1, 2, …, 58; L_k, SA_k, Cr_k , BL_k represent independent variables: the number of dockers, the storage area, the number of quay cranes and the berth length respectively; through $\beta_1, \beta_2, \beta_3, \beta_4$ denote the coefficients of independent input variables, which are to be estimated in the regression model; the term e_k is the statistical error component.

The regression analysis revealed a relatively strong fit of the equation with R^2 equal to 0.99486, which means 99.5% of the variation in terminal container throughput is explained by the variation in input variables. The estimated coefficients are depicted in the table below:

Table 6: The coefficients estimated by Regression Analysis (Case 1)

Variables	Coefficient	St. error	t-statistic	P-value	Lower 95%	Upper 95%
Y-intercept	0	N/A	N/A	N/A	N/A	N/A
Ln L	1.60361009	0.1404716	11.415901	5.12686E-16	1.3219814	1.88523873
Ln SA	0.20621528	0.1178019	1.7505251	0.085707399	-0.0299634	0.44239399
Ln Cr	0.11667583	0.1559001	0.7484014	0.457465413	-0.1958849	0.42923664
Ln BL	-0.3309312	0.1014421	-3.262269	0.001918742	-0.5343103	-0.1275521

However, the analysis of the coefficients has shown another result. The test statistic for each variable shows that only total storage area and berth length affect total container throughput at the confidence level $\alpha = 5\%$ (p-values < 0.05), while the number of dockers and the number of quay cranes are not significant and don't explain the variation in container output, which is unreasonable.

Moreover, berth length has a negative coefficient, which is unexpected and economically meaningless. Several reasons could be accountable for this result including specification problems, measurement errors and the aggregation of several types of output in a single measure (Wang, 2004). When the independent variable has a functional relationship with other independent variables, the relationship between dependent and independent variables can't be explained with other variables held constant. In this case, the terminal area is likely to have a functional relationship with other variables such as berth length. The area of the terminal is usually equal to the length of the quayside berth times its width. As a result, the unreasonable negative coefficient is present in the model.

Due to the presence of multicollinearity between different independent variables in the regression model, the results of the further model building may be inaccurate and the coefficient estimates may change erratically in response to small changes in the model or the data. We need to sort out the original data, thus, we computed the correlation matrix to find correlated independent variables.

Table 7: Correlation between the variables

	L	*SA*	*Cr*	*BL*	***Y***
L	1				
SA	0.815683123	1			
Cr	0.81918847	0.716291064	1		
BL	0.697419982	0.79563248	0.654894104	1	
Y	0.999997853	0.81543418	0.819040129	0.697010171	1

This result shows a strong correlation between a dependent variable and predictor variables, which is reasonable. The matrix confirms that berth length has a high correlation with other variables. For instance, the close relationship with quay cranes, which can be explained by the fact, that terminal infrastructure and equipment increase widely in proportion. So, we decide to do data feature scaling for variable berth length in the following step.

Most of the time, when the dataset will contain features highly varying in magnitudes, units and range, if left alone, these algorithms only take in the magnitude of features neglecting the units. The results would vary greatly between different units, and further affect the accuracy of model building. To suppress this effect, we need to bring all features to the same level of magnitudes. This can be achieved by data scaling. In our case, we use the average volume of berth length to conduct data normalization, trying to correct the problem that the coefficient of this variable is negative in the previous regression model.

After the data scaling of the variable Berth Length, we conducted a new regression analysis without original berth length data, instead of it, we used a new normalized variable Terminal scale to represent terminal infrastructure. While the number of quay cranes variable was deleted since it doesn't contribute to explaining the total variation a lot and has a very strong correlation with terminal scale. The regression result is shown below.

Table 8: The coefficients estimated by Regression Analysis (Case 2)

Variables	Coefficient	St. error	t-statistic	P-value	Lower 95%	Upper 95%
Y-intercept	0	N/A	N/A	N/A	N/A	N/A
Ln L	1.3183901	0.08496	15.51709	9.57E-22	1.148119467	1.48866183
Ln SA	0.105200	0.11094	0.948291	0.347129	-0.1171221	0.32752303
ln TS	0.231847	0.10455	2.217566	0.030735	0.022323694	0.44137106

Besides, we have conducted a regression analysis with different combinations of two independent variables. The results of multiple regression analysis with two predictor variables (the number of dockers and the area of storage) are presented in the table below. The model has an equation R^2 equal to 0.99424, which means 99.4% of the variation in terminal container throughput is explained by the variation of these two independent variables, and both coefficients are positive, a relatively strong fitful regression model was revealed.

Table 9: The coefficients estimated by Regression Analysis (Case 3)

Variables	Coefficient	St. error	t-statistic	P-value	Lower 95%	Upper 95%
Y-intercept	0	N/A	N/A	N/A	N/A	N/A
Ln L	0.2746665	0.094212	2.915408	0.005099778	0.0859372	0.4633959
Ln SA	1.3977063	0.014922	93.66578	3.09458E-63	1.3678134	1.4275993

The regression analysis here helped us figure out the rationality of variable selection and the accuracy of data collected. Even it also indicates how or to what extent variables are associated with each other. But it couldn't define the inefficiency while separating statistical noise. The regression doesn't take into account the statistical noise of random variables, such as weather and other events beyond control. It gives no efficiency scores, but only an inaccurate efficiency ranking based on technical inefficiency measured by statistical error.

Due to multicollinearity, we also couldn't include all factors we have chosen from the first stage of research in the model that, as we think, affect the throughput handling efficiency of container terminals. The most accurate regression model was built with only two independent factors.

With this in mind, our hypothesis is that two or three independent variables can afford to explain the variance of the dependent variable. In the following section, we considered conducting a Principle components analysis (PCA) to check if only two or three variables could be competent for building a model, which explains the variance of the dependent variable at a high level. If the two independent variables are fair enough for further research, then we could build the parametric model based on this, which could also define the production frontier and calculate both technical efficiency and random shocks.

4.3.2. Principle components analysis

Known the results of regression analysis, we have noticed that not all of the factors we decided to include in the model are suitable, only through data scaling we could build a reasonable regression model. However, it would be better to further collate data before conducting an SFA analysis.

In the research and application in many fields, it is often necessary to observe a large number of variables reflecting things and collect a large number of data to analyze and find the rules. The multivariable large sample will undoubtedly provide rich information for research and application, but in most cases, there may be a correlation between many variables, thus increasing the complexity of problem analysis and bringing inconvenience to analysis. And due to multicollinearity, the accuracy of the model would be strongly affected as well. However, if each index is analyzed separately, the analysis is often isolated rather than comprehensive. Blindly reducing indicators will lose a lot of information and easily lead to wrong conclusions.

Therefore, it is necessary to find a reasonable method to keep the information contained in the original indicators while reducing the number of indicators that need to be analyzed, so as to achieve the purpose of a comprehensive analysis of the collected data. Because there is a certain correlation between the variables, it is possible to synthesize all kinds of information in each comprehensive indicator. The Principle Component Analysis (PCA) is a common dimensionality reduction technology.

According to the situation we encountered in the research process, there exists a high-level of multicollinearity among selected factors. The result is shown below.

Table 10: The result of Principle Component Analysis

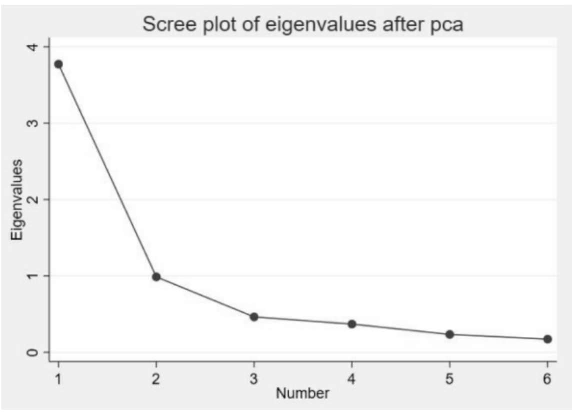
Component	Eigenvalue	Difference	Proportion	Cumulative
PC1	3.77316	2.78554	0.6289	0.6289
PC2	0.987615	0.524211	0.1646	0.7935
PC3	0.463404	0.093927	0.0772	0.8707
PC4	0.369476	0.135453	0.0616	0.9323
PC5	0234023	0.0617009	0.0390	0.9713
PC6	0.172323		0.0287	1.0000

As the result shows, only the PC1 has an eigenvalue of more than 1. The PC2 is close to 1, which reveals that among all the selected variables, most of the variance can be explained by two principal components. We can say that there are 2 most important principle components, and the equation of cumulative proportion equals 0.7935, which means they can explain almost 80% of the dependent variable's variances.

If we want to be more specific, we could still use 3 or 4 principal components, and they can explain 87.07% and 93.23% of the variance in the data, but the inaccuracy of model building would increase as well. With all the 6 components the whole variance of the dependent variable can be explained.

We can see from the scree plot of the eigenvalues after PCA shown below: after the PC3, almost the curve becomes a straight line and PCs have less significance, which also supported the opinion that two or three variables could be competent for conducting further research.

Figure 12: The scree plot of the eigenvalues of Principle Component Analysis



4.3.3. Stochastic Frontier Analysis

With all the analysis results above, we decided to further conduct a parametric model building with the independent variables of the number of dockers, the storage area, the terminal scale, and the number of quay cranes. Again, the log-linear Cobb-Douglas form was used to estimate container terminals' efficiency to the stochastic production frontier model, as presented in the equation.

$$\ln Y_k = \beta_0 + \beta_1 \ln L_k + \beta_2 \ln SA_k + \beta_3 \ln TS_k + \beta_4 \ln Cr_k + v_k - u_k$$

where Y_k specifies the dependent output variable of the kth container terminal, $k = 1, 2,\ldots, 58$; L_k, S_k, TS_k, Cr_k represent independent variables: the number of dockers, the storage area, the terminal scale and the number of quay cranes respectively; through $\beta_1, \beta_2, \beta_3, \beta_4$ denote the coefficients of independent input variables, which are to be estimated in the regression model; the disturbance term v_k is the statistical noise component; u_k is referred to as the inefficiency component, which should be positive. The nonnegative distribution component (a measurement of inefficiency) is assumed to be from a truncated normal distribution.

The result of the SFA analysis is shown in the table below.

Table 11: The coefficients estimated by SFA method (Case 1)

ln*Y*	**Coef.**	**Std. Err.**	**z**	**P>|z|**	**[95% Conf. Interval]**
Ln *L*	2.256725	4.66e-06	4.8e+05	0.000	[2.256715, 2.256734]
Ln SA	.0512272	6.43e-07	8.0e+04	0.000	[.512259, .512284]
Ln *TS*	.0146423	3.87e-07	3.8e+04	0.000	[.146416, .146431]
Ln *Cr*	-.0797563	5.90e-07	-1.4e+05	0.000	[-.0797574, -.0797551]
_cons	-4.252196	.000023	-1.8e+05	0.000	[-4.252241, -4.252251]
Usigma					
_cons	5.22708	8.148243	0.64	0.521	[-10.74318, 21.19734]
Vsigma					
_cons	-49.15811	13350	-0.00	0.997	[-26214.68, 26116.37]
sigma_u	13.64728	55.60066	0.25	0.806	[.0046467, 40081.56]
sigma_v	2.12e-11	1.41e-07	0.00	1.000	[.0000000, .0000000]
lambda	6.45e+11	55.60066	1.2e+10	0.000	[6.45e+11, 6.45e+11]

The SFA model which included four most important factors has a relatively high likelihood to fit the variance, which is 74.96%. The P>|z| in this model is equal and close to zero, indicated that this model is quite fit for the explanation of data collection as well. The independent variables selected do have a significant influence on the Y dependent variables. However, the coefficient of the number of quay cranes is negative, which is unreasonable and makes no sense.

The estimated efficiency scores for container terminals range from 0,041696 to 0,988976, which are quite conform to the actual situation, some container terminals were working efficiently while some not. The terminals with a higher score of efficiency are almost located on the production frontier and those terminals who have low efficiency, could considering improving performance by focusing more on the variable of the storage area, which is confirmed having more influence on the output container throughput.

But the model still could be improved. As in the case of Regression Analysis estimation, we deleted correlated and insignificant independent variables from the model and conducted another Stochastic Frontier Analysis. We have tried every different possible combination of different variables. When computing the efficiency scores with three independent variables (the storage area, the terminal scale and the number of quay cranes), we again received improved analysis results, with the technical efficiency scores in the range of 0,445217 to 0,984439. It has indicated the technical efficiency from the point of view of three predictor variables and revealed that these three variables are the most important factors for the container terminals' throughput handling performance. The number of dockers is removed from the model, which could be explained by the fact that the dockers working at the terminals are the supplement of the quay cranes. The machine equipment has a more significant influence than the workers who support their job.

Table 12: The coefficients estimated by SFA method (Case 2)

ln*Y*	**Coef.**	**Std. Err.**	**z**	**P>|z|**	**[95% Conf. Interval]**
Ln SA	.0504624	.1281823	0.39	0.694	[-.2007702, .3016951]
Ln *TS*	.10986	.0880782	1.25	0.212	[-.6277, .28249]
Ln *Cr*	.9387436	.1344737	6.55	0.000	[.6577363, 1.219751]
_cons	5.706585	.3777756	15.11	0.000	[4.966159, 6.447012]
Usigma					
_cons	-.0390831	.3166818	-0.12	0.902	[-.6597681, .5816018]
Vsigma					
_cons	-3.127415	.700419	-4.47	0.000	[-4.500211, -1.754619]
sigma_u	.9806481	.1552767	6.32	0.000	[.7190071, 1.337498]
sigma_v	.2093584	.0733193	2.86	0.004	[.1053881, .4159003]
lambda	4.684063	.1933381	24.23	0.000	[4.305128, 5.0622999]

While the SFA method gives more information about the factors which have significant influence on the terminals' container throughput handling capacity, allows ordering terminals by technical efficiency score, and shows what can be improved by comparing inefficient terminals with the best in the industry, like linear regression approach, a disadvantage also exists that it doesn't tolerate multicollinearity among independent variables. Since the SFA method also did not allow us to account for all factors that influence container terminals' throughput handling performance, we considered more elabourated methods in the following research stage.

4.4. Envelopment Data Analysis

The DEA method has two specifications: input-oriented and output-oriented. The task of the first specification is to minimize input while satisfying at least the given output level. The latter maximizes output without increasing input size. As we described before, in the given research the output model was assumed, because it is more logical and easier for container terminals to work with output data, due to relatively high cost and inflexibility of most inputs.

There are several assumptions for data that should be used in DEA analysis. First of all, the input and output data interpreted in the model should be non-negative, otherwise, it will be meaningless. Besides, the number of DMUs n should be satisfied by the rule:

$$n \geq \max\{m * s, 3(m + s)\}$$

The M refers to the number of Inputs, while the S represents the number of outputs This requirement declares the statistical influence of chosen data. In empirically oriented methodologies there is a problem involving degrees of freedom, if we will not have an appropriate number of samples, the model building results may have been influenced. In the envelopment model, the number of degrees of freedom will increase with the number of DMUs and decrease with the number of inputs and outputs. A rough rule of thumb is described by the equation. Our sample satisfies the rule of data robustness because of 58 companies ≥ 12 (3*(Number of Inputs + Number of Outputs)).

Apart from the requirements of sample size, the types of variables are also subject to certain constraints. The model must ensure the company's power to control the size of inputs in a reasonable range. Logically speaking, the DEA results will provide a suggestion for companies to improve their performance. If the researchers will use in the model the variables, which couldn't be controlled by the managers, then there will be no meaning to conduct such research. From a managerial viewpoint, it means that managers can manage all tangible assets of the company and, hence, influence the company's throughput capacity. In the DEA model that we are about to build, the suggestions will be provided in order to achieve the target of output maximization. Besides this, considering the waste of resources and unreasonable investment, the DEA model will also give suggestions about the usage of every input. If the inputs are consumed at a suitable level, there will be no changes. However, if the DMU can achieve a better level of production with even fewer inputs, the advice about such changes will also be provided by the DEA output-oriented model results.

Since there is no information on the returns to scale of the sample container terminals' production function, both the CCR and BCC models were applied to estimate the efficiency scores. Since the DEA model can accept a large number of variables, and provide suggestions based on each of the variables included in the model, we decided to include in the model three most influencing inputs, the total container storage area, the terminal scale and the number of quay cranes, obtained as final analysis results of SFA model. The efficiency score results without and with considering the scale returns and the descriptive statistics are shown in the table below.

Table 13: Descriptive statistics of efficiency scores of the container terminals

Measure	**Efficiency**	
	CCR	**BCC**
Average	0,4015	0,5159
Standard deviation	0,2805	0,3474
Minimum	0,0365	0,0372
Maximum	1	1

The average efficiency scores derived by CCR and BCC are 0.40 and 0.52, while the number of efficient terminals (the score is equal to 1) is 2 and 9 out of 58 respectively. This result is not surprising, since the model with constant returns to scale (CCR) identifies both pure technical and scale efficiency, while the model with variable returns to scale provides information only on technical efficiency.

The two container terminals (Shanghai port Shengdong Container Terminal, Guangzhou Container Terminal) have the efficiency score of 1 and they are the examples of best practice and serve as the reference group to other terminals in both models, which means no matter what kind of returns to scale they have, the four container terminals have the best industry practice, and could be seen as learning examples of other terminals.

The Chinese terminals were revealed to have higher efficiency on average from technical and scale point of view. The container terminals which could be seen as fully efficient are all from China. The best practice among Russian container terminals is the Vostochniy VICS Terminal. Other Russian container terminals such as Ust-Luga Container Terminal, have relatively high-efficiency scores in the BBC model, while in CCR model they have really low scores. Considering the difference between CCR and BBC model we could get the conclusion that among these container terminals the scale efficiency is much high than the average level.

Besides, half of the selected sample terminals still operate at 50% to 70% of the maximum efficiency level, which means their performance is under the optimal levels. There were no regional patterns discovered among the least performing container terminals. Some examples of terminals with the lowest efficiency scores are Chinese Guangzhou Nansha Container Terminal and Russian Novorossiysk JSC NUTEP terminal. The Russian Novorossiysk Commercial Sea Port PJSC Container Terminal has the lowest efficiency score from both models.

The sum of independent variables coefficients shows the return to scale that can be divided into three categories: increasing, decreasing, and constant. The container terminal has an increasing return to scale when an increase in output level is proportionately more than an increase in its input level. On the contrary, decreasing return to scale means an increase in output level is less than a proportionate increase in input level. Otherwise, if the proportions of input and output stay the same, the terminal production has a constant return to scale. 12 out of 58 terminals fall into a constant return to scale category, meaning that the terminal facilities had been fully utilized within their reference group. The rest 33 terminals exhibit increasing returns to scale. Increasing return suggests that terminals are operating under their optimal levels due to excess capacity and that production should be scaled up to reduce such inefficiencies. Though, there are many terminals having the scale efficiencies close to 1, which indicates the rational utilization of resources and that the main source of inefficiency is closely related to the technology gap. In other words, both underperformed container terminals and most efficient ones have some room to improve their level of technical efficiency.

One of the benefits of DEA analysis is that it provides a slack analysis, which shows excess capacities of inputs or shortages of outputs. The underperforming terminals are compared with the best practice container terminals within the reference group to identify potential areas for improvements. The analysis identifies target values, which underperforming terminals should achieve to obtain the optimal productivity level relative to the reference group.

For instance, in the assessment with the assumption of increasing returns to scale (the BBC model) the suggested target values for Vostochniy VICS Terminal are shown in the table below.

Table 14: The slack analysis for Vostochniy VICS Terminal (Russia)

Input/Output	Actual value	Target value	Difference	%
The storage area,	204200	179338	24812	-12.175
The terminal scale	0.724304	0.558218	0.166086	-22.931
The number of cranes	6	6	0	0
Throughput 2018, TEU	419200	2224442	1805242	430.64

In the Difference column, positive or negative signs indicate the percentage of the actual values of the variables to be increased or reduced, respectively. Vostochniy VICS Terminal (Russia) has excess capacity in the year 2018, where it should reduce 12.125% and 22.931% of the total storage area and the terminal scale, respectively, to achieve the optimal throughput level of 430.64% increasing based on actual value. While the number of quay cranes is appropriate to support the new target of throughput. As the model shows, the container throughput handling capacity of Vostochniy VICS Terminal could achieve more than four times potential growth, such improvement may be quite surprising. If the DMU can adopt the advice given by the DEA model, although no guarantee will be of such a four-fold increase as the number indicated, the improvement it can obtain is still satisfactory.

While the SFA method focuses on the economic justification and hypothesis testing, to find the relationship between inputs and output and define the importance level of various facilities, indicate the operational efficiency, the slack analysis and projection results of DEA provide insights for the increase of output or reduction of input resources consumption to improve efficiency. Both the results of DEA and SFA in a combination can support management to have a more comprehensive understanding of the throughput handling capacity of Sino-Russian container terminals and to identify the status of efficiency and causes of inefficiency.

4.5. Summary of chapter 4

In this chapter, we have conducted an empirical analysis of the container throughput handling capacity study of container terminals. The whole study has consisted of three stages. We started the research with qualitative methodology in the first stage. The questionnaires, interviews and document analysis helped us select optimal variables from a series of options, communicating with industry experts and authorities, top/middle manager of terminals' operating companies, access to primary industry practical experience and professional knowledge.

In the second stage, before conducting the Stochastic Frontier Analysis, we have used the average production function and Principle Components Analysis to check whether all the collected original data are suitable for further research and whether all the factors selected in the first stage of the study should be included in the further model building. After this process, we have removed from the model some insignificant predict variables and normalized the data of berth length into the variable terminal scale. Finally, we have built the SFA model, identified that the most important factors to influence the container terminals' throughput handling capacity are the total container storage area, the terminal scale, and the number of quay cranes. These factors are bused to answer the second research question.

The third question about the methods to improve the terminals' container throughput handling capacity was analysed by the Data Envelopment Analysis. This model has provided suggestions for each container terminal to improve their throughput handling capacity. We have also implied such a model on the Russian Vostochniy VICS Terminal as a practical example, to introduce how the terminal should manage its inputs to achieve the target best container throughput handling capacity.

Conclusion

With the fast-growing demand for international logistics service, maritime transportation, especially container terminals, plays an important role in world trade cooperation. Highlighting the context of the “Belt and Road initiative” and special strategic relationship between Russian and China, the main purpose of this research was to estimate the throughput handling capacity of container terminals involved in the “Belt and Road initiative” by applying various study methodologies and to explore for the potential of improvement. Evaluation of container throughput handling capacity was based on the operational terminal facilities data from 58 seaports’ container terminals serving in the Sino-Russian cross-border trade in 2018.

The empirical study was organized into three stages. At the first stage, the qualitative methodology was used to identify the terminal inputs, which have a significant influence on the handling performance, through the questionnaires and interviews with industry experts and managers of terminals’ operating companies. Then with the target to test every input we selected, at the second stage, the average production function and Principle Components Analysis were conducted at the beginning. We removed the inputs, which have relatively less influence and finally, built a mathematical function through Stochastic Frontier Analysis. Through this parametric quantitative method, we have finally identified the most important facilities for the terminals’ container throughput handling capacity, which are the total area for storage of containers, the number of quay cranes, and a composite index of the terminal scale, which integrates the berth’s characteristics of the length and depth. Under the guidance of this model conclusion, managers can implement effective and purposeful investment construction to avoid excessive investment or waste of resources. And the model also indicated to which level these factors are affecting the throughput capacity of container terminals. The subsequent application of the DEA model in the third stage allowed us to define the reasons for inefficiency and obtain the estimates of the potential for increasing the throughput handling capacity for the container terminals in the sample.

Each of the chosen measurement approaches has its benefits and limitations. Based on the industry knowledge we initially identified the corresponding influencing factors with lower persuasion. Next the regression Analysis and Principle Components Analysis identified the significance of independent variables in explaining dependent argument and removed the limitations of predictor variables with a high degree of multicollinearity. The SFA method solves the problem with random shocks, calculating both technical efficiency and random error by constructing frontier production function. The benefits of the DEA approach are that it allows making a complex evaluation of container terminals’ assets without creating sophisticated cost. DEA doesn’t have strict requirements for the independence of variables, allowing a user of multiple inputs and outputs. the design of given research allows identifying the dependence of variables by Regression Analysis method, estimating technical efficiency with the account of random shocks by the SFA method, identifying reference group, calculating technical efficiencies as well as slacks by the DEA method. Using the analysis results of SFA and DEA as a strategic performance indicator helps container terminals' operators improve their performance. The high score of efficiency means that the size of infrastructure is just right, while the low score indicates that the terminal may need to change its production arrangement to obtain the optimal efficiency level.

The cross-country analysis showed that container terminals' throughput handling capacity varies among regions. Chinese container terminals are found to be more efficient. A possible explanation of this could be the high utilization of resources and a huge amount of investment on the terminals' equipment, the location of Chinese south seaports on the main trade routes and the economic growth of China also motivate the efficiency improvement, the same as the usage of the most advanced technology, can bring great potential for improvement. Whereas the container terminals from Russian famous port city Saint-Petersburg are found to perform relatively poorly, even they have strong capital support and equipped with advanced technology. This phenomenon probably could be explained by excess capacity and unreasonable production structure. More than half of the terminals show increasing returns to scale, which determines an incentive to invest in the infrastructure to expand throughput handling capacity.

Among the possible limitations of this research can be that we used the cross-sectional data of the year 2018, rather than panel data of terminals' facilities and throughput handling. The throughput handling performance research should be dynamic and data from different years is required. Since it is more reasonable and convincing from the economic point of view to measure the capacity through a period, considering the changes of different terminal inputs during this time. Moreover, the interview of the research also indicated that, the terminal digitalization also could be seen as a significant factor that affects the container throughput capacity. Our hypothesis is the relationship between container throughput handling capacity and the level of terminal digitalization is positively related. We were collecting the data of terminals' digitalization, such as the investment in digitalization or the number of smart equipment. However, because the tendency of industry digitalization started not long ago and most terminal operating companies do not have enough accurate data for us to conduct the research. Since port digitalization is gaining more and more attention, construction in this area will keep going and relevant data will be supplemented until it can be used for research. It is particularly interesting to study the relationship between the terminal digitalization and container throughput handling capacity.

Reference

1. oglu Nasirov, A. Y. (2018). Importance of Silk Road in the International Trade. Argos, 35(70).
2. Fels, E. (2018). The Geopolitical Significance of Sino-Russian Cooperation in Central Asia for the Belt and Road Initiative. In Rethinking the Silk Road (pp. 247-267). Palgrave Macmillan, Singapore.
3. Chen, Y., & Liu, Y. (2016). Study on the Economic Logic of ‘the Belt and Road’ Initiative of China. Chinese Business Review, 15(12), 573-584.
4. Bulis, A., & Skapars, R. (2014). Development of “New Silk Road” Northern Branch through Seaport of Riga in Latvia. Procedia-Social and Behavioral Sciences, 150, 1222-1229.
5. Li, P., Qian, H., Howard, K. W., & Wu, J. (2015). Building a new and sustainable “The initiative Belt and Road”. Environmental Earth Sciences, 74(10), 7267-7270.
6. Blanchard, J. M. F., & Flint, C. (2017). The geopolitics of China’s maritime silk road initiative.
7. Roh, K. D. (2019). Different Versions of Romance: Recent Studies on Sino-Russian Relations. Journal of Chinese Political Science, 1-9.
8. Panibratov, A. (2017). Russian oil and gas MNEs investing in China: The role of government in value creation. In Value creation in international business (pp. 279-306). Palgrave Macmillan, Cham.
9. Garnett, S. (2001). Challenges of the Sino-Russian strategic partnership. Washington Quarterly, 24(4), 41-54.
10. Hsu, J. Y., & Soong, J. J. (2014). Development of China-Russia Relations (1949-2011) Limits, Opportunities, and Economic Ties. Chinese economy, 47(3), 70-87.
11. Christoffersen, G., & Zuenko, I. (2018). Northeast China and the Russian Far East: Positive Scenarios and Negative Scenarios. In International Relations and Asia’s Northern Tier (pp. 215-238). Palgrave, Singapore.
12. Yu, G., & Wang, R. (1999). Conception of establishing the Sino-Russian border free economic region. Chinese Geographical Science, 9(3), 236-242.
13. Paik, K. W. (2015). Sino-Russian Gas and Oil Cooperation–Entering a New Era of Strategic Partnership.
14. Bolt, P. J., & Cross, S. N. (2010). The contemporary Sino-Russian strategic partnership: Challenges and opportunities for the twenty-first century. Asian Security, 6(3), 191-213.
15. Yeung, C., & Bjelakovic, N. (2010). The Sino-Russian strategic partnership: views from Beijing and Moscow. The Journal of Slavic Military Studies, 23(2), 243-281.

16. Pirchner Jr, H. (2008). The uncertain future: Sino-Russian relations in the twenty-first century. Demokratizatsiya, 16(4), 309.
17. Lain, S. (2015). The Bear and the Dragon: Same Old Suspicions or Real Pivot East. The RUSI Journal, 160(1), 68-77.
18. Heaver, T. D. (2002). The evolving roles of shipping lines in international logistics. International Journal of Maritime Economics, 4(3), 210-230.
19. Steenken, D., Voß, S., & Stahlbock, R. (2004). Container terminal operation and operations research-a classification and literature review. OR spectrum, 26(1), 3-49.
20. Slack, B., & Frémont, A. (2005). Transformation of port terminal operations: from the local to the global. Transport Reviews, 25(1), 117-130.
21. Liu, Q. (2010). Efficiency analysis of container ports and terminals (Doctoral dissertation, UCL (University College London)).
22. Caldeirinha, V. R., Felicio, J. A., & Coelho, J. O. A. N. A. (2009). The influence of characterizing factors on port performance, measured by operational, financial and efficiency indicators. Recent Advances in Environment, Energy Systems and Naval Science, 58-70.
23. Chrzanowski, I., & Wiater, S. J. (1985). An introduction to shipping economics. Fairplay Pubns.
24. Esmer, S. (2008). Performance measurements of container terminal operations.
25. Henesey, L. (2004). Enhancing container terminal performance: a multi agent systems approach (Doctoral dissertation, Blekinge Institute of Technology).
26. Wanke, P. F., Barbastefano, R. G., & Hijjar, M. F. (2011). Determinants of efficiency at major Brazilian port terminals. Transport Reviews, 31(5), 653-677.
27. Bergantino, A. S., Musso, E., & Porcelli, F. (2013). Port management performance and contextual variables: Which relationship? Methodological and empirical issues. Research in Transportation Business & Management, 8, 39-49.
28. Tovar, B., & Rodríguez-Déniz, H. (2015). Classifying ports for efficiency benchmarking: A review and a frontier-based clustering approach. Transport Reviews, 35(3), 378-400.
29. Perez, I., Trujillo, L., & González, M. M. (2016). Efficiency determinants of container terminals in Latin American and the Caribbean. Utilities Policy, 41, 1-14.
30. Wiegmans, B., & Witte, P. (2017). Efficiency of inland waterway container terminals: Stochastic frontier and data envelopment analysis to analyze the capacity design-and throughput efficiency. Transportation Research Part A: Policy and Practice, 106, 12-21.

31. Nguyen, H. O., Nghiem, H. S., & Chang, Y. T. (2018). A regional perspective of port performance using metafrontier analysis: the case study of Vietnamese ports. Maritime Economics & Logistics, 20(1), 112-130.
32. Liu, B. L., Liu, W. L., & Cheng, C. P. (2008, October). The efficiency of container terminals in mainland China: An application of DEA approach. In 2008 4th International Conference on Wireless Communications, Networking and Mobile Computing (pp. 1-10). IEEE.
33. Wu, J., Yan, H., & Liu, J. (2009). Groups in DEA based cross-evaluation: An application to Asian container ports. Maritime Policy & Management, 36(6), 545-558.
34. Wu, J., Yan, H., & Liu, J. (2010). DEA models for identifying sensitive performance measures in container port evaluation. Maritime Economics & Logistics, 12(3), 215-236.
35. Shui-Mu Ju & Nan Liu (2015) Efficiency and its influencing factors inport enterprises: empirical evidence from Chinese port-listed companies, Maritime Policy &Management, 42:6, 571-590.
36. Nguyen, H. O., Nguyen, H. V., Chang, Y. T., Chin, A. T., & Tongzon, J. (2016). Measuring port efficiency using bootstrapped DEA: the case of Vietnamese ports. Maritime Policy & Management, 43(5), 644-659.
37. Sun, J., Yuan, Y., Yang, R., Ji, X., & Wu, J. (2017). Performance evaluation of Chinese port enterprises under significant environmental concerns: An extended DEA-based analysis. Transport Policy, 60, 75-86.
38. Huang, X., Chen, H., Wang, Y., & Piao, H. (2018, April). Research on Port Efficiency Measurement Based on Three-stage Cascade Data Envelopment Analysis Control Strategy. In Proceedings of the 2018 International Conference on Information Science and System (pp. 43-49).
39. Yang, X., & Yip, T. L. (2019). Sources of efficiency changes at Asian container ports. Maritime Business Review.
40. XU, Y., & ISHIGURO, K. (2019). Measuring the Efficiency of Automated Container Terminals in China and Korea. Asian Transport Studies, 5(4), 584-599.

Appendix
Questionnaire

Hello! Welcome to the container terminals' throughput handling capacity survey!

The purpose of this questionnaire survey is to conduct research on the container terminals' throughput handling performance measurement. Please choose the importance of the following indicators based on your extensive experience and knowledge. The results are used for academic research only. Sincerely appreciate your support and cooperation!

Please choose the appropriate option according to the actual situation.

1. What is your occupation?

A. Researchers
B. Enterprise managers
C. Other

2. Are you concerned about the measurement and improvement of container port throughput handling capacity?

A. Yes
B. No

3. Are you willing to accept further face-to-face interview?

A. Yes
B. No

4. Are you concerned about container ports working in Sino-Russian trade?

C. Yes
D. No

5. What is your judgment on the prosperity of the Sino-Russian container transportation market?

A. Optimism
B. Pessimistic
C. Uncertain prospects

6. What do you think is the biggest problem in container port operation at present?

A. Technology innovation
B. Service quantity
C. Data collection and analysis
D. New idea
E. Other

Please give an evaluation of the importance of the following indicators that affect the container terminals' throughput handling performance.

1. Among the inputs affecting terminal's performance, **the Number of Labours**

   A. Very Important B. Important C. Not Important D. Not Sure

2. Among the inputs affecting terminal's performance, **the Number of Dockers**

   A. Very Important B. Important C. Not Important D. Not Sure

3. Among the inputs affecting terminal's performance, **the Terminal Quay Length**

   A. Very Important B. Important C. Not Important D. Not Sure

4. Among the inputs affecting terminal's performance, **the Number of Berths**

   A. Very Important B. Important C. Not Important D. Not Sure

5. Among the inputs affecting terminal's performance, **the Container Berth Length**

   A. Very Important B. Important C. Not Important D. Not Sure

6. Among the inputs affecting terminal's performance, **the Container Berth Depth**

   A. Very Important B. Important C. Not Important D. Not Sure

7. Among the inputs affecting terminal's performance, **Area of Terminal Storage Space**

   A. Very Important B. Important C. Not Important D. Not Sure

8. Among the inputs affecting terminal's performance, **the Area of Yard Space**

   A. Very Important B. Important C. Not Important D. Not Sure

9. Among the inputs affecting terminal's performance, **the Number of Gantry Cranes**

   A. Very Important B. Important C. Not Important D. Not Sure

10. Among the inputs affecting terminal's performance, **the Handling Equipment**

    A. Very Important B. Important C. Not Important D. Not Sure

Please give an evaluation of the importance of the following indicators that represent the container terminals' throughput handling performance.

11. Among the outputs representing terminal’s performance, **the Cargo Throughput**
    A. Very Representative   B. Representative   C. Not Representative   D. Not Sure

12. Among the outputs representing terminal’s performance, **the Container Throughput**
    A. Very Representative   B. Representative   C. Not Representative   D. Not Sure

13. Among the outputs representing terminal’s performance, **the Customer Satisfaction**
    A. Very Representative   B. Representative   C. Not Representative   D. Not Sure

14. Among the outputs representing terminal’s performance, **Rate of Freight handling**
    A. Very Representative   B. Representative   C. Not Representative   D. Not Sure

15. Talk about your views on the current development of the shipping industry?

16. If there are any deficiencies in this questionnaire, be free to give any suggestions.

Thank you very much for your support and cooperation! Best wishes!

The efficiency score estimated by DEA

DMU	CCR		BBC		
	Score	Rank	Score	Rank	Returns to scale
Chiwan Container Terminal	0.338	34	0.5914	26	Decreasing
Dalian Container Terminal	0.7023	8	1	1	Decreasing
PSA DGST Container Terminal	0.7778	6	0.9792	12	Increasing
Fujian Jiangyin International Container terminal	0.944	4	1	1	Increasing
Fuzhou Qingzhou Container Terminal	0.4009	30	0.4969	30	Increasing
Fuzhou Xingang International Container Terminal	0.6743	9	0.6966	16	Increasing
Nansha Container Terminal	0.5764	17	0.6182	24	Decreasing
Guangzhou Nansha Container Terminal	0.1717	46	0.1934	46	Decreasing
Guangzhou Container Terminal	1	1	1	1	Constant
Guangzhou Nansha Port Container Terminal	0.4545	26	0.4725	31	Increasing
Jinzhou port Container Terminal	0.3238	35	0.3391	40	Increasing
Jinzhou Xinshidai Container Terminal	0.716	7	1	1	Increasing
Quanzhou port Jinjiang Container Terminal	0.1832	44	0.2206	45	Increasing
Ningbo Daxie Me International Container Terminal	0.5104	23	0.5276	28	Decreasing
Ningbo Port Beilun No.3 Container Terminal	0.5915	16	1	1	Decreasing
Ningbo Meishan International Container Terminal	0.975	3	0.985	11	Increasing
Ningbo Port Beilun No.2 Container Terminal	0.4683	25	0.5142	29	Decreasing
Quanzhou Container Terminal	0.3665	31	0.3702	36	Increasing
Xiamen International Container Terminal	0.2308	42	0.2332	44	Increasing
Xiamen Haicang Xinhaida Container Terminal	0.3025	38	0.3650	37	Increasing
Xiamen Container Terminal	0.2623	39	0.3214	41	Decreasing
Shanghai port Jiujiang Container Terminal	0.3489	33	1	1	Increasing
Shanghai port Shangdong Container Terminal	0.4379	28	0.4704	33	Increasing
Shanghai port Yidong Container Terminal	0.6468	13	0.6686	21	Decreasing
Shanghai port Zhendong Container Terminal	0.5221	21	0.8129	14	Decreasing
Shanghai port Guandong Container Terminal	0.8526	5	0.8705	13	Increasing
Shanghai port Hudong Container Terminal	0.6236	14	0.6643	22	Decreasing
Shanghai port Mingdong Container Terminal	0.6560	12	0.7050	15	Increasing
Shanghai port Pudong Container Terminal	0.6113	15	0.6175	25	Increasing
Shanghai port Shengdong Container Terminal	1	1	1	1	Constant
Shekou port Container Terminal	0.4401	27	0.6798	19	Decreasing
Taicang port Shanggang Container Terminal	0.3210	36	0.3425	39	Increasing
Taicang port international Container Terminal	0.3618	32	0.4554	34	Increasing
Tianjin port Container Terminal	0.4703	24	0.4713	32	Increasing
Tianjin Port Union International Container Terminal	0.6669	10	0.6738	20	Increasing
Tianjin Port Pacific International Container Terminal	0.6578	11	0.6861	18	Increasing
Wenzhou Yang Kim Container Terminal	0.5449	20	1	1	Increasing
Wuhan port Container Terminal	0.5733	19	1	1	Increasing
Yantai International Container Terminal	0.2256	43	0.2907	42	Increasing
Yantian International Container Terminal	0.3046	37	0.3461	38	Increasing
Yangzhou Yuanyang Container Terminal	0.2586	41	0.4197	35	Increasing
Yinkou port Container Terminal	0.5764	17	0.6262	23	Increasing
Yinkou Xinshiji Container Terminal	0.5215	22	0.5534	27	Increasing
Zhangjiagang Yongjia Container Terminal	0.4064	29	0.6948	17	Increasing
Zhuhai Gaolan International Container Terminal	0.2617	40	0.2622	43	Increasing
SPb First Container Terminal	0.0739	49	0.0912	50	Decreasing

SPb Container Terminal	0.0888	48	0.1117	49	Decreasing
Port Bronka Container Terminal	0.0473	53	0.0479	55	Increasing
Petrolesport Container Terminal	0.0531	52	0.0534	53	Increasing
Vostochniy VICS Terminal	0.1805	45	0.1885	47	Increasing
Kaliningrad Commercial port Container Terminal	0.0595	50	0.0599	51	Increasing
Baltic Stevedore's Container Terminal	0.0436	56	0.0468	56	Increasing
Ust-Luga Container Terminal	0.0446	55	0.9991	10	Increasing
Novorossiysk JSC NUTEP Terminal	0.0537	51	0.0557	52	Decreasing
Novorossiysk Sea Port PJSC Container Terminal	0.0365	58	0.0372	58	Increasing
JSC "Novoroslesexport" Container Terminal	0.0469	54	0.0482	54	Increasing
Vladivostok Sea Fishing port Container Terminal	0.0383	57	0.0398	57	Increasing
Commercial port of Vladivostok Container Terminal	0.1186	47	0.1206	48	Increasing

List of figures

Figure 1: The production function frontier……………..…………………………….…….….11
Figure 2: The efficiency frontier…………………………………………...……….....….13
Figure 3: The Sino-Russian trade volume 2000-2017……………………………….…….23
Figure 4: The China's Belt & Road Initiative……………………………..….....……28
Figure 5: The volume of ports with container terminals growth……………………..…...….30
Figure 6: The largest ports in China…………………………….……………………….31
Figure 7: The Russian ports location……………………………………………….…....32
Figure 8: The Northern Sea Route (NSR)………………………..……………….…..……33
Figure 9: The stochastic production frontier………………………………………...…….40
Figure 10: The production possibility set of 8 DMUs………………..……………...…...…44
Figure 11: The CCR and BCC efficient frontiers…………………………………....…….46
Figure 12: The scree plot of the eigenvalues of Principle Component Analysis……………….…..57

List of tables

Table 1: Summary of performance indicators suggested by UNCTAD……………………..………14
Table 2: Functional forms applied in SFA studies………………………………………..…..….40
Table 3: Variables for measuring throughput handling capacity in the first stage………..……..50
Table 4: Variables for measuring throughput handling capacity…………………………..…..52
Table 5: Descriptive statistics of inputs and output variables of the chosen sample………….....53
Table 6: The coefficients estimated by Regression Analysis (Case 1)……………………..……54
Table 7: The correlation between the variables……………………………………........….54
Table 8: The coefficients estimated by Regression Analysis (Case 2)……………….……….…55
Table 9: The coefficients estimated by Regression Analysis (Case 3)……………………….....55
Table 10: The result of Principle Component Analysis…………………….……...….…………57
Table 11: The coefficients estimated by SFA method (Case 1)……………………..…………..58
Table 12: The coefficients estimated by SFA method (Case 2)…………………………………59
Table 13: Descriptive statistics of efficiency scores of the container terminals………...……....61
Table 14: The slack analysis for Russian Vostochniy VICS Terminal……….………...….…62